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THE EXPERIMENTAL BASIS OF CHEMICAL FORMULAE AND THE TEACHING OF THE ATOMIC-MOLECULAR HYPOTHESIS.

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While an appreciable number of chemists, some of whom are very prominent, are not wholly in sympathy with the atomic hypothesis,[1] there are but few, I think, who would hesitate to acknowledge the practical importance of chemical formulæ. A formula may be interpreted as representing two things: (1) the relative amounts, by weight, of the constituent elements of the substance, each symbol representing a fixed weight of the corresponding element; and (2) the number and kind of atoms in each molecule of the substance. The first interpretation is independent of the second and may be used without reference to the atomic-molecular hypothesis.

In teaching beginners the use of formulæ in either one or both of the above senses it is obviously out of the question to follow, in any faithful detail, the historical development of the subject.[2] Even an approximate adherence to the historical sequence certainly involves perplexing difficulties for the student. Although there is no question that, in all possible cases, Avogadro's hypothesis is, *at present,* the touchstone on which atomic weights and formulæ are tested, nevertheless this hypothesis was opposed by Dalton, who thought it was contradicted by certain well-known facts. The discovery by Dumas that the vapor densities of sulphur, phosphorus, and mercury were 3, 2, and ½ times those previously assumed on the basis of Avogadro's hypothesis led this famous chemist, in 1832, to abandon the hypothesis. Even Berzelius, the master chemist of his day, who had, up to

[1] See, for example, Ostwald, J. Chem. Soc. London, 85, 506 (1904).

[2] Those teachers who, thinking to follow the historical plan, start with the statement that Dalton proposed his hypothesis to explain the facts summarized in the laws of definite and multiple proportions are, apparently, not in accord with the facts; since, as Roscoe and Harden very clearly point out, (The Origin of Dalton's Atomic Theory, Macmillan & Co., 1896), Dalton first employed the atomic hypothesis to explain, by the difference in the weights of their atoms, the difference in solubility of various gases.

this time, been one of the few able supporters of Avogadro's hypothesis, now conceded that the hypothesis was not universally valid.[3]

The open disagreement among chemists as to which of two or more "combining weights" of an element was to be selected as its atomic weight led Wollaston to propose, in 1814, the Doctrine of Equivalents. His idea was to replace atomic weights, based upon hypotheses, by equivalent weights, based as he thought, upon experimentally determined facts. Although Wollaston's idea was welcomed and ardently championed by many, the facts epitomized by the Law of Multiple Proportions show that the assignment to an element of a definite equivalent weight was just as much an arbitrary process as was the fixing of its atomic weight in any manner previously employed. The history of chemistry shows that Wollaston's lamentable fallacy proved an Old Man of the Sea on the back of the science, that was not shaken off for more than forty years.

The remarkable clearness with which Cannizzaro, in 1858, showed[4] that Avogadro's hypothesis was not in conflict with any known fact, and that by the acceptance of this hypothesis order could be brought out of what might well be called chaos, led, as is well known, to the establishment of modern atomic weights and formulæ.

While the historical plan of presenting a subject is ordinarily the preferable one, it is, in this case, in my opinion, impracticable for beginners. If then one decides to forego the historical treatment, he may be free to teach the significance and use of formulæ without, at first, any reference to the atomic-molecular hypothesis, and this is, I think, a distinct advantage from the standpoint of simplicity. Later in the course, after the student has become quite familiar with formulæ and equations and a greater range of chemical facts, it will be an easy matter to introduce the atomic-molecular hypothesis.

The following pages contain an outline of the topics under discussion as I have presented them to my classes during the past school year. The outline consists of two parts: the first deals with the derivation of chemical formulæ without reference to any hypothesis; the second with the interpretation of the facts in terms of the hypotheses of Dalton and Avogadro. The argu-

[3] See Ladenburg, History of Chemistry, Chaps. IV and VI.
[4] Ostwald's Klassiker der Exakten Wissenschaften, No. 30.

ments as here presented may be considered merely a syllabus of the subject: in many cases illustrative explanations, in greater or less detail, must take the place of the brief general statements. The pupil should be able to appreciate the arguments regarding formulæ after the following subjects have been considered: (1) The Conservation of Matter; (2) The limited decomposability of matter and the Doctrine of Elements; (3) The Law of Definite Composition; (4) The Laws of Gases.

1. The Experimental Basis of Chemical Formulæ.

One may weigh a known volume, measured at definite temperature and pressure, of any gaseous substance and then calculate, by the laws of gases, the weight of one liter of the gas at 0° C. and 760 mm. Many pure liquid or solid substances are volatile at temperatures somewhat above the ordinary. The vapors of such substances may be treated as gases and, in each case, the weight of one liter may be calculated for standard conditions.

Every pure substance has a definite composition; this composition is found, in any case, as the result of a specific quantitative experiment. This result may be expressed in terms of the percentage of each constituent element. Table 1 shows the weight of one liter, under standard conditions, and the percentage composition of 32 substances, which are either gaseous at ordinary temperatures or are easily volatile. The values for the densities of gases were, as a rule, taken from Landolt, Börnstein, and Meyerhoffer Tables, 1905, p. 222. Most of the vapor densities of liquids and solids were taken from an extensive table in Lothar Meyer's Die Modernen Theorien der Chemie. All other values were taken from original sources. It has been my aim to give as weights of 1 l. of gas or vapor, in both Tables 1 and 4, only actual, experimentally determined, values. The abbreviation of the name of the observer is appended to each value. These abbreviations are as follows:

B., Berthelot; Ds., Dumas; D. P., Dumas and Peligot; D. T., Deville and Troost; D. M., Daccomo and V. Meyer; E. L., Emmerling and Lengyel; G., Garzarolli and Schacherl; I., Izarn; Jq., Jaquelain; K., Kolbe; Lo. Löwig; L., Leduc; M. L., Mond, Langer and Quincke; Mt., Mitcherlich; P., Pebal; Ra., Rayleigh; Rg., Regnault; Rc., Roscoe; R. S., Ramsay and Steele; S., Saus-

sure; Sa., Salet; Th., Thenard; Tm., Thomson; Ti., Tilden; V. M., Victor Meyer; W. D., Wöhler and Deville.

Table 1.

	Weight of 1 Liter	Percentage of Each Constituent				
		Oxygen	Hydrogen	Carbon	Nitrogen	Chlorine
Oxygen	1.4296 Ra.	100.00				
Water	0.8063 Rg.	88.81	11.19			
Carbon Monoxide	1.2503 L.	57.14		42.86		
Carbon Dioxide	1.9766 Ra.	72.73		27.27		
Nitrous Oxide	1.978 L.	36.35			63.65	
Nitric Oxide	1.341 D.M.	53.31			46.69	
Nitrosyl Chloride	2.987 Ti.	24.44			21.40	54.16
Hypochlorous Oxide	3.889 G.	18.41				81.59
Chlorine Dioxide	3.013 P.	47.43				52.57
Phosgene	4.532 E.L.	16.17		12.13		71.70
Methyl Alcohol	1.440 R.S.	49.95	12.58	37.47		
Ethyl Alcohol	2.086 G.L.	34.74	13.13	52.13		
Methyl Ether	2.091 D.P.	34.74	13.13	52.13		
Ethyl Ether	3.340 R.S.	21.60	13.60	64.80		
Hydrogen	0.0900 Ra.		100.00			
Hydrogen Chloride	1.642 L.		2.76			97.24
Prussic Acid	1.226 G.L.		3.73	44.42	51.85	
Chloroform	5.430 Ds.		0.84	10.05		89.11
Ammonia	0.7722 L.		17.76		82.24	
Methane	0.7212 Tm.		25.15	74.85		
Acetylene	1.190 B.		7.75	92.25		
Ethylene	1.274 S.		14.38	85.62		
Ethane	1.390 K.		20.13	79.87		
Propylene	1.937 B.		14.39	85.61		
Benzene	3.557 R.S.		7.75	92.25		
Methyl Chloride	2.238 D.P.		5.99	23.77		70.24
Ethyl Chloride	2.870 Th.		7.81	37.22		54.97
Methyl Amine	1.396 I.		16.23	38.65		45.12
Nitrogen	1.2506 L.				100.00	
Cyanogen	2.335 G.L.			46.13	53.87	
Cyanogen Chloride	2.754 Sa.			19.52	22.79	57.69
Chlorine	3.221 L.					100.00

The values given in Table 1 represent direct experimental results. Thus, for example, in the case of water, as a result of four determinations at about 100° and 350 mm., Regnault[5] found the weight of one liter of water vapor to be 0.8063 g. for 0° C. and 760 mm.; and Morley[6] found the composition to be 11.19 per cent of hydrogen anl 88.81 per cent of oxygen.

The weight of hydrogen contained in 1 l. of water vapor, at standard conditions, is, of course, 0.1119×0.8063 g$=.090$ g. The weight of any other element in one liter of any other vapor, at standard conditions, may be found in a similar manner. These

[5] Ann. Chim. Phys., [3], 15, 145 (1845).
[6] Smithsonian Reports, 1895.

derived data, which are given in Table 2, represent experimentally determined facts just as truly as do those of Table 1.

From an inspection of the figures in Table 2, the student will have no trouble in seeing two important relationships. It will appear (1) that for any one element there is an approximate *minimum weight* per liter; and (2) that all other weights per

Table 2.

	Weight per Liter of Each Constituent				
	Oxygen	Hydrogen	Carbon	Nitrogen	Chlorine
Oxygen	1.4296				
Water	.716	.090			
Carbon Monoxide	.715		.536		
Carbon Dioxide	1.437		.540		
Nitrous Oxide	.719			1.259	
Nitric Oxide	.715			.626	
Nitrosyl Chloride	.730			.639	1.618
Hypochlorous Oxide	.717				3.172
Chlorine Dioxide	1.429				1.584
Phosgene	.733		.550		3 249
Methyl Alcohol	.720	.180	.539		
Ethyl Alcohol	.725	.273	1.089		
Methyl Ether	.726	.274	1.091		
Ethyl Ether	.722	.454	2.164		
Hydrogen		.090			
Hydrogen Chloride		.045			1.597
Prussic Acid		.046	.545	.635	
Chloroform		.046	.545		4.839
Ammonia		.137		.635	
Methane		.181	.540		
Acetylene		.092	1.098		
Ethylene		.183	1.091		
Ethane		.280	1.110		
Propylene		.279	1.658		
Benzene		.276	3.281		
Methyl Chloride		.134	.532		1.572
Ethyl Chloride		.224	1.068		1.578
Methyl Amine		.226	.540	1.630	
Nitrogen				1.2506	
Cyanogen			1.077	1.258	
Cyanogen Chloride			.537	.628	1.589
Chlorine					3.221

liter of that element are approximate *multiples of the minimum weight*. These relationships may be stated as laws and called the Law of Minimum Weights and the Law of Multiple Weights respectively: they are real natural laws.

For the five elements comprised in Table 2, the minimum weights per liter are approximately as follows:

Hydrogen ..... .045
Oxygen ..... .715
Nitrogen ..... .628
Carbon ..... .536
Chlorine 1.583

It is obvious that the laws of minimum and multiple weights, which have been deduced for the volume one liter, must hold equally well for any other fixed volume. By choosing a certain larger volume the minimum weight of hydrogen, for that volume, may be made approximately 1 gram. All of the other minimum weights will then be greater than 1 gram, and several of them will be approximately whole numbers. In a volume of 22.4 l. the minimum weights, in grams, are approximately as follows:

Hydrogen	1.0
Oxygen	16.0
Nitrogen	14.0
Carbon	12.0
Chlorine	35.5

It follows also that the weight of any element in 22.4 l. of a gas or vapor, under standard conditions, is approximately an even multiple of the minimum weight of that element contained in 22.4 l.

It is quite clear that the numerical relationships just discussed are only approximate. For any one element, say oxygen, we may state the law of multiple weights in either one of the two following ways: (1) The weight of oxygen in *exactly* 22.4 l. of any gas or vapor, under standard conditions, is either *approximately* 16 g. or *approximately* a multiple of 16 g. by a small whole number; or, (2) The weight of oxygen in *approximately* 22.4 l. of any gas or vapor, under standard conditions, is either *exactly* 16 g. or an *exact* multiple of 16 g. by a small whole number. The last column of Table 3 shows the exact volume (nearest 22.4 l.) in which the weight of oxygen, for any substance, is either exactly 16 g. or an exact multiple of 16 g. by a small whole number. The weights of hydrogen, nitrogen, carbon and chlorine which combine with exactly 16 g. or some exact multiple of 16 g. of oxygen, as given in Table 3, are also given. It will be seen that the weight of carbon, for example, is, in any case, either 12.00 g. or an exact multiple of 12.00 g. by a small integer. The weight of each other element combined, in any case, with the weight of oxygen indicated in that case in Table 3 is an exact multiple by unity or some other small integer of a characteristic weight which is approximately the minimum weight, in 22.4 l., for that element. These weights for the other elements under consideration are as follows: hydrogen, 1.008 g.; chlorine, 35.45 g.; nitrogen, 14.01 g.

In the case of a compound which does not contain oxygen, if that volume, nearest 22.4 l., is found in which the weight of any one of its elements is an exact multiple of the weight just given for that element, then, for that compound, in the volume so fixed, the weight of every other element is also an exact multiple of its characteristic weight. In other words Table 3 shows that the composition, by weight, of any compound can be exactly expressed in terms of small integral multiples of certain characteristic numbers, one for each element. This is one form of statement of the Law of Reciprocal Proportions.

Table 3.

	Oxygen	Hydrogen	Carbon	Nitrogen	Chlorine	Wght.	Volumes
Oxygen	2×16.00					32.00	22.38
Water	1×16.00	2×1.008				18.02	22.34
Carbon Monoxide	1×16.00		1×12.00			28.00	22.40
Carbon Dioxide	2×16.00		1×12.00			44.00	22.25
Nitrous Oxide	1×16.00			2×14.01		44.02	22.25
Nitric Oxide	1×16.00			1×14.01		30.01	22.38
Nitrosyl Chloride	1×16.00			1×14.01	1×35.45	65.46	21.92
Hypochlorous Oxide	1×16.00				2×35.45	86.90	22.35
Chlorine Dioxide	2×16.00				1×35.45	67.45	22.39
Phosgene	1×16.00		1×12.00		2×35.45	98.90	21.82
Methyl Alcohol	1×16.00	4×1.008	1×12.00			32.03	22.23
Ethyl Alcohol	1×16.00	6×1.008	2×12.00			46.05	22.07
Methyl Ether	1×16.00	6×1.008	2×12.00			46.05	22.02
Ethyl Ether	1×16.00	10×1.008	4×12.00			74.08	22.18
Hydrogen		2×1.008				2.02	22.44
Hydrogen Chloride		2×1.008			1×35.45	36.46	22.21
Prussic Acid		1×1.008	1×12.00	1×14.01		27.02	22.04
Chloroform		1×1.008	1×12.00		3×35.45	119.36	21.98
Ammonia		3×1.008		1×14.01		17.03	22.05
Methane		4×1.008	1×12.00			16.03	22.23
Acetylene		2×1.008	2×12.00			26.02	21.87
Ethylene		4×1.008	2×12.00			28.03	22.00
Ethane		6×1.008	2×12.00			30.05	21.62
Propylene		6×1.008	3×12.00			42.05	21.70
Benzene		6×1.008	6×12.00			78.05	21.96
Methyl Chloride		3×1.008	1×12.00		1×35.45	50.47	22.55
Ethyl Chloride		5×1.008	2×12.00		1×35.45	64.49	22.47
Methyl Amine		5×1.008	1×12.00	1×14.01		31.05	22.24
Nitrogen				2×14.01		28.02	22.40
Cyanogen			2×12.00	2×14.01		52.02	22.28
Cyanogen Chloride			1×12.00	1×14.01	1×35.45	61.46	22.32
Chlorine					2×35.45	70.90	22.12

Suppose we represent by H 1.008 g. of hydrogen and by O 16.00 g. of oxygen; then, since 2×1.008 g. of hydrogen combine with 16.00 g. of oxygen, 2 H together with O, which we may write H_2O, will represent the composition of water and, more-

over, that quantity of water which as vapor under standard conditions would occupy approximately 22.4 l. H and O are the *symbols* for hydrogen and oxygen respectively and H_2O is the *formula* for water. Similarly N represents 14.01 g. of nitrogen; C. 12.00 g. of carbon; and Cl. 35.45 g. of chlorine. The composition of any compound of these five elements may be exactly expressed by a formula constructed from the appropriate symbols. Thus C_2H_6O represents the composition of alcohol and shows that in approximately 22.4 l. of the vapor, under standard conditions, there are contained 2×12.00 g. of carbon united with 6×1.008 g. of hydrogen and 16.00 g. of oxygen. The formulæ of the elementary gases studied are H_2, O_2, N_2 and Cl_2, since each of these gases contains in approximately 22.4 l. double the weight represented by the symbol of the corresponding element.

The argument here presented is essentially an elaboration of that of Cannizzaro, made fifty years ago, to which reference has already been made. Table 4 is a reproduction, abbreviated in length only, of Cannizzaro's principal table, which included values for 26 additional substances.

Table 4.

NAME OF THE SUBSTANCE	Weight of one volume or molecular weight referred to the weight of a half hydrogen molecule = 1	Weight of the constituents of one volume or of one molecule, all referred to the weight of a half hydrogen molecule = 1
Hydrogen	2	2 Hydrogen
Oxygen.....	32	32 Oxygen
Hydrochloric Acid.	36.5	35.5 Chlorine, 1 Hydrogen
Water..	18	16 Oxygen, 2 Hydrogen
Ammonia.....	17	14 Nitrogen, 3 Hydrogen
Alcohol.	46	6 Hydr'g'n, 16 Oxyg'n, 24 Carb'n

It is evident that Cannizzaro's figures for the "weight of one volume" are rounded, *idealized* values. In my own tables *experimentally observed* gas densities have been used in order to make the treatment more concrete and to show as clearly and directly as possible the experimental basis of chemical formulæ.[8]

The scheme which I have followed in the cases of five elements and their compounds may be extended so as to embrace a large

[8] Prof. Alexander Smith has called my attention to the chapter on symbols, formulas and equations in Linebarger's Elementary Chemistry, (Rand, McNally & Co., Chicago, 1904) where the plan of treatment is somewhat similar to that which I am advocating. The author gives, in a single table, the weights of 1 liter of 12 gases or vapors and the weights of hydrogen, carbon, oxygen and nitrogen in one liter of each substance. The weights per liter, in most cases, are not the *real, observed* values, but, like Cannizzaro's, are those which evidently have been calculated from the formulae, on the assumption that gas densities are *strictly proportional to formulae weights*.

proportion of the commoner elements. The following table, Table 5, gives the name of one volatile compound of each common element in which the minimum weight of that element per liter of vapor is contained. The minimum weights in 22.4 l. given in column 2, are *approximately* the weights represented by the corresponding symbols. The *exact* weight represented by the symbol, in any case, is found as the result of a very accurate determination of the composition of some compound of the element with an element of known symbol weight.

In the cases of those elements which form volatile compounds, the symbol weights, as found in the manner discussed in the preceding pages, multiplied by the respective specific heats of the solid elements give approximately the same product. This, law, discovered by Dulong and Petit in 1819, may be applied to find the approximate symbol weights of those elements which do not readily form volatile compounds: the exact values represented by the symbols are found, as in other cases, by very accurate quantitative analyses or syntheses.

In the case of any volatile substance, the formula is written so as to represent the number of symbol weights of each constituent in approximately 22.4 l. of the vapor, under standard conditions. If we now indicate in terms of formulæ, so constructed, the relative amounts of the reacting substances we have *equations*, such as the following: $2H_2+O_2 \longrightarrow H_2O$.

It is an experimentally established fact that, at a fixed temperature and pressure, 2 volumes of hydrogen unite with one volume of oxygen to form 2 volumes of steam. The equation indicates that 2×22.4 l. of hydrogen unite with 22.4 l. of oxygen to form 2×22.4 l. of water vapor, approximately, for standard conditions. In all cases, *coefficients of formulæ*, in equations for substances wholly in the gaseous state, *show the relative reacting volumes*.

II. The Atomic-Molecular Hypothesis.

Perhaps the best mental picture of the nature of matter is afforded by the *Atomic-Molecular Hypothesis*, according to which all matter is conceived of as composed of minute indivisible particles, called atoms. This ancient Greek hypothesis was reintroduced into chemistry by Dalton in 1803. Dalton supposed the atoms of a simple substance to be all alike in size, weight, and all other properties. Atoms of like or different sorts were

supposed by Dalton to combine or unite in simple ratios, by numbers; e. g., 1:1; 1:2; 1:3; 2:3; etc.; the groups of atoms so formed are now called molecules. For example, according to Dalton's hypothesis, one molecule of any definite hydrogen com-

Table 5.

Volatile Compounds of Various Elements	Density Air = 1	Weight of El. in 22.4 l.	Symbol and Symbol Weight
Antimony Trichloride	7.8 Mt.	119.5	Sb = 120.2
Arsenic Trichloride	6.30 Ds.	75.4	As = 75.0
Bismuth Trichloride	11.35 Jq.	217.	Bi = 208.5
Boron Trichloride	4.02 W. D.	10.9	B = 11.0
Hydrogen Bromide	2.71 Lo.	78.	Br = 79.96
Cadmium	3.94 D. T.	114.	Cd = 112.4
Chromium Oxychloride	5.69 Ds.	55.	Cr = 52.1
Methyl Fluoride	1.186 Ds. P.	19.2	F = 19.0
Hydrogen Iodide	4.443 G. L.	127.7	I = 127.97
Iron Carbonyl	6.45 M. L.	53.2	Fe = 55.9
Lead Chloride	9.6 Rc.	207.2	Pb = 206.9
Mercury	6.98 Ds.	202.2	Hg = 200.0
Nickel Carbonyl	6.01 M. L.	59.7	Ni = 58.7
Phosphorus Trichloride	4.88 Ds.	31.9	P = 31.0
Silicon Tetrachloride	5.94 Ds.	28.7	Si = 28.4
Zinc Chloride	4.57 V. M.	63.5	Zn = 65.4

pound will contain 1, 2, 3, or some small integral number of hydrogen atoms; similarly one molecule of a definite oxygen compound will contain some small integral number of oxygen atoms. If, now, we suppose these two compounds to interact, so that water is formed by the union of the hydrogen of the first with the oxygen of the second; and if, according to the atomic hypothesis, the atoms of hydrogen and oxygen unite in simple ratios; then, as a necessary consequence, the numbers of molecules of the two reacting substances must be in the ratio of small whole numbers. Similarly, for all substances, according to Dalton's hypothesis, molecules must react with one another; in numbers which, in any given case, may be represented by a simple ratio.

When gases react, in any particular case, at a fixed temperature and pressure, the volumes of the initial substances, and also of the products if gaseous, are in simple ratios. From a consideration of the facts represented by this *Law of Volumes*, first stated by Gay Lussac in 1808, and of the hypothesis of Dalton, we may reach a very important conclusion, namely: That the numbers of molecules in equal volumes of all gases at the same temperature and pressure are either *equal* or in a *simple ratio*.

In 1811 Avogadro advocated the hypothesis that equal volumes of all gases or vapors at the same temperature and pressure contain equal numbers of molecules. Since this supposition represents one of the several possibilities, according to the Dalton Hypothesis and the Gay Lussac Law, it is therefore in complete accord with the facts so far discussed as well as with the views of Dalton. Modern investigation has shown, however, that Gay Lussac's Law is not mathematically exact; but is only a close approximation, the deviations amounting usually to less than one per cent. The strict modern statement of Avogadro's hypothesis is that equal numbers of molecules are contained in approximately equal volumes of gases or vapors, at the same temperature and pressure.

Each molecule of any definite substance contains, according to Dalton's hypothesis, a definite small number of atoms of one or more sorts; but each molecule cannot contain less than one atom of any given element; consequently the minimum number of atoms of that element per liter is the same as the number of molecules per liter, which is the same for all gases. Therefore a gas in which each molecule contains but one atom of a given element, will contain the minimum possible weight per liter of that element. This, then, is the theoretical explanation of the Law of Minimum Weights. On the other hand, in a gas which contains more than the minimum weight of a given element per liter, each molecule must contain 2, 3, 4 or some small whole number of atoms of the element and therefore one liter of the gas must contain 2, 3, 4 or some small integral multiple of the minimum weight per liter of that element; and this is the explanation of the Law of Multiple Weights.

According to the arguments just discussed, a gas which contains the minimum weight per liter of any element must have but one atom of that element in each molecule. Equal volumes of such gases contain the same number of atoms of the element of minimum weight per liter, since they contain the same number of molecules. The minimum weights per liter are, therefore, the relative weights of equal numbers of atoms. The weights of equal volumes of various gases or vapors are proportional to the weights of their respective molecules.

But, as we do not know, very exactly, the absolute weight of any atom or molecule, a value may be assigned arbitrarily as the weight of any sort of atom; the weight of every other sort of

atom or molecule may then be expressed on the same basis. The values so obtained are called atomic or molecular weights. Dalton's atomic and molecular weights were based upon the atomic weight of hydrogen chosen as unity. Berzelius chose at one time oxygen with an atomic weight of 100 as the basis of calculation. Most chemists of to-day prefer values based on oxygen with an atomic weight of 16; but obviously the choice of a standard is an arbitrary matter.

The following example will serve to show how atomic and molecular weights are found from the experimental data. Water contains the minimum weight of oxygen per liter (Table 2); therefore each molecule of water contains but one atom of oxygen. If, now, we take 16 as the weight of one atom of oxygen, the weight of a molecule of water is 18.016; since 16.00 g. of oxygen are contained in 18.016 g. of water. The weight of hydrogen combined with 16.00 g. of oxygen is 2.016 g. But water contains twice the minimum weight of hydrogen per liter (Table 2) and therefore two atoms of hydrogen in each molecule or to each atom of oxygen. If 16.00 is taken as the atomic weight of oxygen, then ½ of 2.016=1.008 is the atomic weight of hydrogen. The atomic weights of oxygen and hydrogen are thus identical with their respective symbol weights. The same relationship holds for all other elements considered.

In Table 3, the factor of any symbol-weight represents the number of atoms of the indicated element contained in one molecule of the substance. The formula-weight, in grams, Table 3, is numerically equal to the molecular weight which is the sum of the weights of the atoms in the molecule, on the basis of 16 as the atomic weight of oxygen. From the standpoint of the atomic-molecular hypothesis, the formula of water, H_2O, represents two atoms of hydrogen combined with one atom of oxygen to form a molecule.

In the foregoing paragraphs I have tried to present in concise form a collection of facts and arguments intended to show that chemical formulae and equations have a direct experimental basis, independent of any hypothesis regarding the structure of matter; and that the symbol and formula weights may be found in a very simple way without reference to the atomic-molecular hypothesis. I have also endeavored to point out how, according to this scheme, the hypotheses of Dalton and Avogadro are readily applied in logical explanation of the facts epitomized by chemical formulae.

THE USE OF THE TELESCOPE IN EXPERIMENTAL OPTICS.

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The most interesting and at the same time the most neglected phase of laboratory physics is undoubtedly the work in optics. Many high school and college courses totally neglect all work in this intensely fascinating and important subject. This seems to be due to four prevalent misconceptions: 1st, that the apparatus required is too expensive; 2nd, that a special dark room is necessary; 3rd, that an unfailing sunlight is essential; and 4th, that there are few experiments worth performing.

The object of this article is to submit a series of fundamental experiments that require no expensive apparatus, dark room, or direct sunlight. I will confine my attention strictly to those that can be performed legitimately with the aid of a telescope, in any ordinary laboratory.

The telescope for this purpose consists of an instrument having a good objective and ocular, but no inversion lenses. A set of fine cross hairs is, however, absolutely essential. A good form of telescope would be one having an objective of about 15 cm. focal length and a draw tube which can, by means of a fine focusing rack and pinion movement, be drawn out about the same distance beyond the adjustment for viewing a distant object.

At my suggestion an instrument of this type has been placed on the market by A. B. Porter, of the Scientific Shop, 324 Dearborn St., Chicago, Ill.

When a telescope is focused on an object it is not sufficient that the image is seen distinctly. The image and cross-hairs must also be free of parallax, viz., when the eye is shifted laterally there must be no relative motion between the image and the cross-hairs, in which case they both lie in the same plane, parallel to the ocular.

Throughout this article the adjustment of no parallax is meant when any reference is made to focussing the telescope, or viewing an image when the telescope has previously been focused.

To focus the telescope on an object, first adjust the ocular so that the cross-hairs are seen distinctly, while the other eye remains open. Now adjust the draw tube until the image of the object viewed becomes distinct and free from parallax with the cross-hairs.

In all work with the telescope the distance from the telescope to the image of the object viewed must always be equal or greater than the shortest distance at which an object can be seen distinctly when viewed directly, with the draw tube adjusted at full length. If 30 cm. is the limit at which the image of an object can be focused distinctly, the distance between the telescope and the image cannot be shorter than 30 cm., but for the best results it should not greatly exceed this distance. On bearing this in mind much difficulty in focussing the telescope on images in curved mirrors and lenses will be avoided.

In experiments with the telescope, mirrors and lenses need not be more than 2 to 3 cm. in diameter, so that fairly accurate accessories can be purchased for the same price as the larger, more imperfect ones generally in use.

In the following experiments several methods for determining the same constant are frequently outlined, so that the student obtains a more intimate knowledge of the laws of mirrors and lenses.

Experiment I. Law of the Plane Mirror.

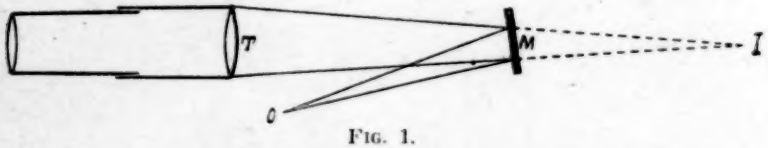


Fig. 1.

In Fig. 1, M represents a plane mirror; T the telescope; and O an object consisting of a fine cross on a piece of paper, metal, or glass.

Focus the telescope on the image I of the object, and measure the distances TM and OM. Remove the mirror, and without altering the focus of the telescope, determine the distance TI at which the object can be seen distinctly (without parallax) when viewed directly.

Measure TI and then calculate MI.

$$OM=MI \ldots\ldots (1)$$

or the image in a plane mirror is virtual and lies as far behind the mirror as the object is in front.

Experiment II. Focal Length and Radius of Curvature of a Concave Mirror.

Method A. Focus the telescope on a distant object, viz., on one several blocks away, and place it in front of a concave mirror

M, Fig. 2. Move an object O to and fro until its image is seen distinctly. The focal length of the mirror

$$F=OM \quad \ldots\ldots (2)$$

and its radius of curvature

$$R=2OM \quad \ldots\ldots (3)$$

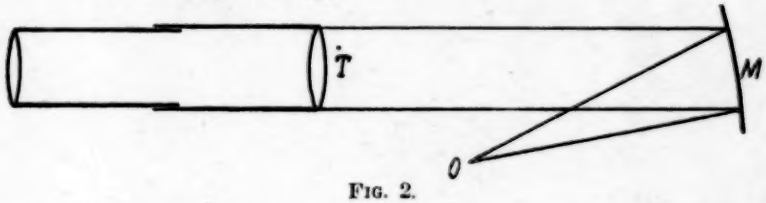


FIG. 2.

Method B. Place the object O, Fig. 3, closer to the mirror M than its principal focus. Focus the telescope on the image, I,

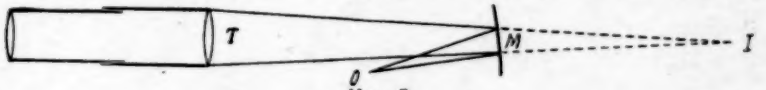


FIG. 3.

of the object, and measure TM and OM. Remove the mirror and locate I as in experiment I. Measure TI and calculate MI

$$\frac{1}{F}=\frac{2}{R}=\frac{1}{OM}-\frac{1}{MI} \quad \ldots\ldots (4)$$

EXPERIMENT III. FOCAL LENGTH AND RADIUS OF CURVATURE OF A CONVEX MIRROR.

Method A. Focus the telescope on the image I of a distant object O, Fig. 4, produced by a convex mirror M. Measure TM.

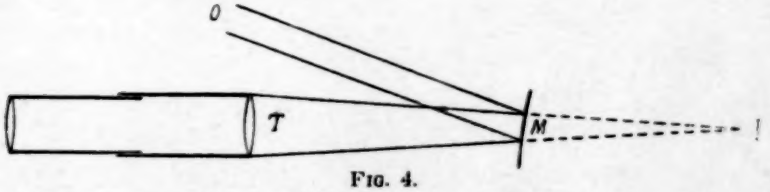


FIG. 4.

Remove the mirror and locate I by moving an object in front of the telescope until it is in focus. Measure TI and calculate MI, the focal length of the mirror.

$$R=2MI \quad \ldots\ldots (5)$$

FIG. 5.

Method B. Focus the telescope on the image I of the object O, Fig. V. Measure MO and TM. Remove the mirror, and locate I as before. Measure TI and calculate MI.

$$\frac{1}{F}=\frac{1}{MI}-\frac{1}{MO} \qquad (6)$$

Experiment IV. Testing Plane Surfaces.

If a beam of parallel light is incident on a surface S, Fig. 6, the reflected rays are divergent if the reflecting surface is convex; convergent, if concave, and parallel if plane.

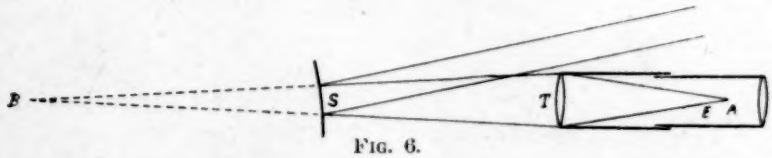


Fig. 6.

If the surface is convex the rays will appear to come from B, and will be brought to a focus by the objective lens, T, of the telescope at the point A, beyond its principal focus E. Thus A and B will be two conjugate foci of the objective lens and

$$\frac{1}{F}=\frac{1}{BT}+\frac{1}{TA}=\frac{1}{BS+TS}+\frac{1}{F+EA}$$

If R represents the radius of curvature of the surface then

$$R=2BS \text{ and}$$

$$\frac{1}{\frac{1}{2}R+ST}=\frac{1}{F}-\frac{1}{F+EA} \qquad (7)$$

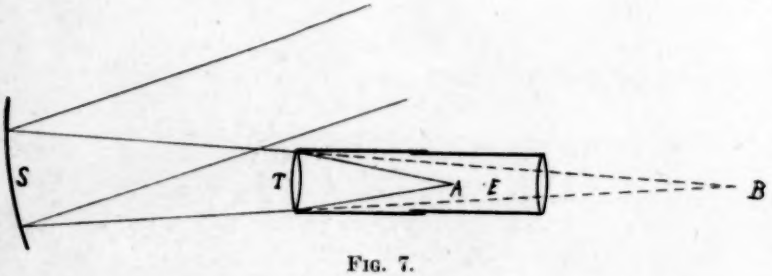


Fig. 7.

If the surface S, Fig. 7, is concave, the light from a distant object will come to a focus at A, in front of the principal focus E of the telescope objective. Then A and B are conjugate foci, and

$$\frac{1}{F}=\frac{1}{TA}-\frac{1}{TB}=\frac{1}{F-AE}-\frac{1}{BS-TS} \text{ or}$$

$$\frac{1}{\frac{1}{2}R-TS}=\frac{1}{F-AE}-\frac{1}{F} \quad \text{(8)}$$

Remove the objective lens, T, of the telescope and determine its principal focal length F. Replace it and focus the telescope on a distant object. Place the telescope a measured distance, ST, from the surface whose curvature is desired and measure the distance AE, which the ocular must be moved in or out to see the object without parallax, when reflected from the curved surface.

If the ocular is drawn out the surface is convex and its radius of curvature is calculated from Eq. (7); if pushed in, the surface is concave and R is obtained from Eq. (8).

Experiment V. The Optical Micrometer.

The optical micrometer consists of a plane mirror M, Fig. 8, mounted on a bar having three pointed legs. The two legs at E are about 2 cm. apart and form an isosceles triangle with the leg G.

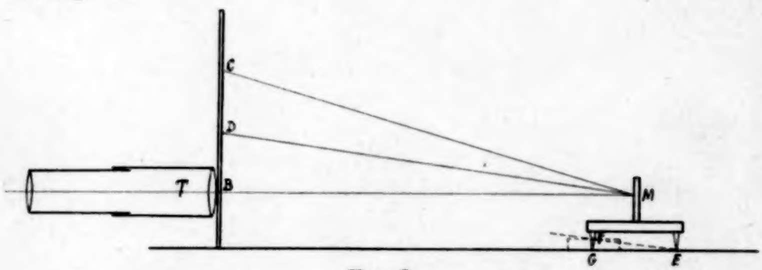


Fig. 8.

Place the lever on a plane piece of heavy plate glass. Mount the telescope, T, about 3 m. from the mirror, M, and fasten a meter stick vertically to the telescope stand. Move the lever and its mirror until the image of the scale is visible in the telescope. Focus the telescope and determine the scale reading, B.

Carefully raise the end, G, of the lever and place under it the object whose thickness is desired. Determine the scale reading C.

The thickness of the object is:

$$FG=\frac{EG\times BC}{2BM} \quad \text{(9)}$$

Experiment VI. Focal Length of a Convex Lens.

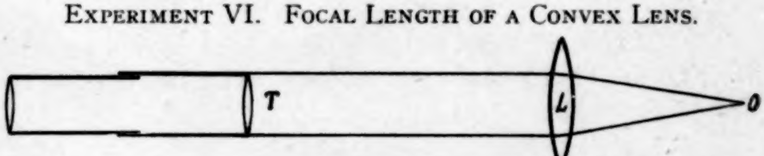


Fig. 9.

Method A. Focus the telescope for parallel rays, viz., on a distant object. Place it in front of the lens L, Fig. 9, and move an object, O, until seen distinctly.

$$F=OL \quad \ldots\ldots (10)$$

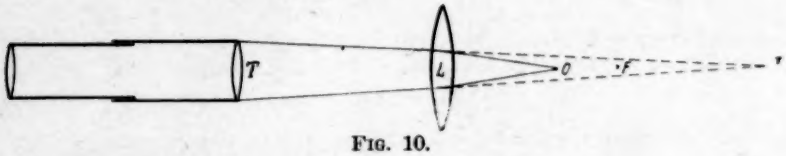


FIG. 10.

Method B. Place an object, O, closer to the lens L, Fig. 10, than its principal focus, and then focus the telescope on its virtual image I. Measure TL and LO. Remove the lens and locate I, as before. Measure TI and calculate LI.

$$\frac{1}{F}=\frac{1}{LO}-\frac{1}{LI}$$

EXPERIMENT VII. FOCAL LENGTH OF A CONCAVE LENS.

Place the telescope in front of the concave lens L, Fig. 11, and focus it on the image I of a distant object. Measure TL. Remove the lens, and determine the position of the virtual image I. Measure TI and calculate the focal length of the lens.

$$F=LI \quad \ldots\ldots (12)$$

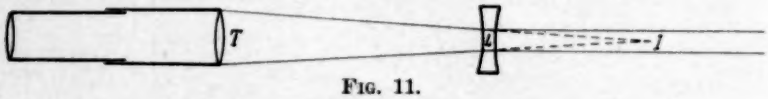


FIG. 11.

Method B. Focus the telescope on the image I of an object O, Fig. 12, placed about 1 m. from the lens. Measure TL and LO. Remove the lens, and determine LI, as before.

$$\frac{1}{F}=\frac{1}{LI}-\frac{1}{LO} \quad \ldots\ldots (13)$$

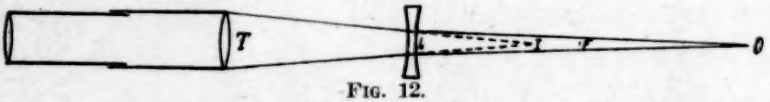


FIG. 12.

EXPERIMENT VIII. INDEX OF REFRACTION OF THE GLASS OF WHICH A LENS IS MADE.

Let F denote the principal focal length of a convex lens, R, and R_2 the radii of curvature of its faces, and n the index of refraction of the glass.

Then $$\frac{1}{F}=(n-1)\left(\frac{1}{R_1}+\frac{1}{R_2}\right) \quad \ldots\ldots (14)$$

Determine the focal length of the lens and the radii of curvature of its faces by means of some of the methods previously given. Substitute these values in the above equation and calculate, n, the index of refraction of the glass of which the lens is made.

EXPERIMENT IX. INDEX OF REFRACTION OF LIQUIDS.

Method A. Place a glass trough in front of the telescope and focus it on a mark O, Fig. 13. Measure BT and the inner length OB of the trough. Fill the vessel with the liquid whose index of refraction is desired and move the telescope back to T′ where the mark is again in focus.

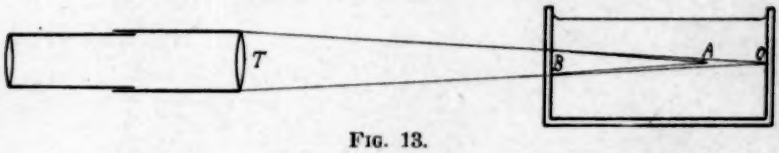


FIG. 13.

Measure BT′.

$$BT'-BT=AO \text{ and}$$

$$n = \frac{OB}{OB-AO} \qquad (15)$$

Method B. In a thin sheet of mica, or tin foil, cut a hole about 3 cm. in diameter. Cement the mica between two plane plates of glass and attach to a divided head. Place the plates in a trough of water, Fig. 14, and focus the telescope, through the opening in the mica, on a distant object. Turn the plate until the image of the object just disappears, and read the divided head. Now rotate the plate in the opposite direction until the image just vanishes and again read the dial.

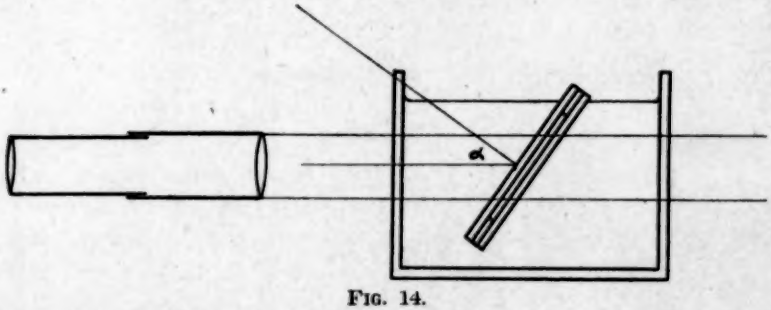


FIG. 14.

Let one half of the angle through which the plates were rotated$=\alpha$. Then

$$n = \frac{1}{\sin \alpha} \qquad (16)$$

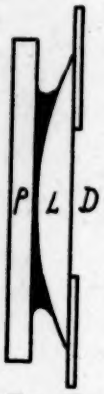


FIG. 15.

Method C. By means of one of the previous methods, such as Ex. III, Method A, determine the radius of curvature of a plano-convex lens. Now mount the lens, L, Fig. 15, in contact with a plane plate of glass, P, and put a few drops of the liquid whose index of refraction is desired between the glass plate and the lens. Place a diaphragm, D, in front of the plate, somewhat smaller than the liquid lens.

Determine the focal length of the combination of lenses. Now dry the plano-convex lens and determine its focal length. Calculate the focal length of the liquid lens from the equation

$$\frac{1}{F_{\text{concave lens}}} = \frac{1}{F_{\text{convex lens}}} - \frac{1}{F_{\text{combination}}} \qquad (17)$$

Now, for any lens

$$\frac{1}{F} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

For the plano-convex lens R_1, is infinite, hence

$$\frac{1}{F} = (n-1)\frac{1}{R} \text{ or}$$

$$n = \frac{F+R}{F} \qquad (18)$$

EXPERIMENT X. SPHERICAL ABERRATION.

Cover the central half of a convex lens with a disc of cardboard, and measure its focal length. Now replace the disc with a diaphragm of the same diameter and repeat the observations.

EXPERIMENT XI. CHROMATIC ABERRATION.

Cover a convex lens with a plate of red glass and very carefully measure its focal length, as in Ex. VI, Method A. Replace the red with a violet plate and repeat the observations.

EXPERIMENT XII. WAVE LENGTH OF LIGHT.

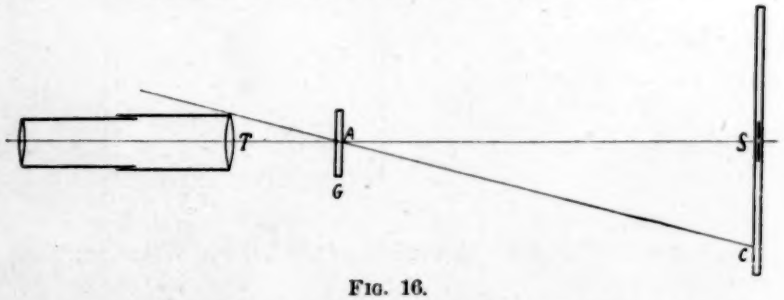


FIG. 16.

Mount a telescope, T, on a bar free to rotate about an axis, A, Fig. 16. Directly above this axis, and at the same height as

the telescope, mount a transmission grating with its rulings vertical. About 2 m. from the grating mount a meter stick horizontally, and at its center place a vertical slit, S, ruled on an exposed, developed photographic negative. The meter stick should be placed at such a height that both the slit and the graduations on the scale can be seen through the telescope at the same time.

Place a Bunsen burner, with a piece of glass in its flame, directly behind the slit, to produce mono-chromatic light.

Focus the telescope on the slit and take the reading of the meter stick directly below.

Turn the telescope, by means of the rotating bar, until the spectrum of the sodium light to the left of the slit coincides with the cross hairs of the telescope. Repeat for the spectrum on the right of the grating and calculate the average distance SC.

If λ represents the wave length of the Na light and d the grating space, then

$$\lambda = d\frac{SC}{CA} \quad \text{.....} \quad (19)$$

These few experiments do not by any means exhaust those that can be performed with the telescope. I have only outlined a few of them, to illustrate its utility in optical experiments. There are also many modifications of the experiments just given. Only a few of the simpler ones have been mentioned, which any average academic student can perform without difficulty.

In case the telescope is mounted on a rod free to rotate about the axis of a divided dial, all the important experiments generally performed with the spectrometer can be worked. Some of the most important of these experiments are:

1. The law of reflection from plane mirrors.
2. The angle of rotation of the normal is one-half of the angle of rotation of the reflected ray.
3. Angle between two objects.
4. Angle of a prism, or crystal.
5. Snell's law of refraction.
6. Index of refraction—prism method.
7. Index of refraction of liquids—hollow prism method.
8. Study of the various types of spectra.
9. Selective absorption.
10. Wave length of light.

The telescope will be found very useful for building up a spectroscope or spectrometer. It has all the essentials of a first class instrument.

PHYSIOLOGY IN THE HIGH SCHOOL.

By H. W. Norris,
Grinnell, Iowa.

Physiological instruction in recent times has shown three phases: 1. A period when it consisted of recitations, in anatomy chiefly, with desultory remarks on hygiene; the committing to memory of lists of bones, muscles, digestive organs, etc. Of the location of the various organs of the body some notion was gained; of the functions and natural workings of the living mechanism the pupil received little adequate information. There was little reference to specimens or demonstrations. 2. The second phase of physiological instruction illustrated the anatomy by the use of the actual specimens and apparatus, but still it was little more than anatomy. 3. The third phrase considers physiology as the study of life, of the functions, use, and normal working of the living mechanism, of the care of the body, of the prevention of disease, of the protection of society by sanitation, etc. Along with the text-book work goes illustrative material.

If the mission of the physician of the future is to be, not primarily the cure of the individual, but the prevention of disease and the protection of society, then it becomes evident that there must be a radical change in the subject matter of a part of our educational curriculum. For if there is any one of the numerous subjects studied by our children in the public schools, of which they are more ignorant than of others, it is of the structure, functions, and laws of health of their own bodies. The ignorance which young people display regarding the most common life processes, their total disregard of most obvious penalties of broken laws, their indifference to nature's lessons, is almost disheartening to us, who as teachers believe that we mold the future.

It has been said that every child has the right to be born well. It is certainly as true that he has the right to be ushered into young manhood in good health and equipped with a knowledge of how to remain physically sound. Good health and good morals are intimately related. Many evils that undermine the moral strength of our youth find germination ground in physical weakness or in ignorance of the normal processes of healthy animals.

There ought to be inculcated in the young a respect for the human body. The best that life holds depends upon the indi-

vidual and his efforts. The common notion that the final responsibility can be shouldered by kind Providence and the doctors, and that in consequence all will be right in the end, is the worst of superstitions. The ascribing of failure to a "mysterious dispensation of Providence" is not only the most inexcusable of blasphemies, and what every thoughtful mind knows to be a cowardly lie, but worst of all gives the young and inexperienced an altogether perverted notion of the relation of cause and effect in the matter of wholesome living. Physiology rightly studied is iconoclastic and destructive to myths and superstition. It makes plain that law holds as inexorably in the living world as elsewhere, and that disobedience to nature's laws never fails of punishment.

Says Professor Jennings: "The reaction to a given stimulus depends upon the physiological condition of the organism." This physiological fact is of the utmost importance to educational psychology. Too long we have acted as though we were teaching disembodied spirits. The remarkable achievements of the ancient Greeks, the profound influence of their ideals in literature, science, and art, was largely due to the fact that they devoted in their educational practice as much attention to the training of the body as to that of the mind.

Good health is a basic element of good citizenship. He serves his day and generation best who lays sound foundations for future generations. Every young person who enters the field of independent activity of his life not only should be physically sound, with corresponding moral condition, but he should understand the basic phenomena of life. It should not be possible for him to expose himself to the insidious attacks of disease, to avoidable accident, in total ignorance of cause, effect and prevention. He needs to know not so much cold hard anatomical facts, as the broad principles of normal living sympathetically interpreted. Of course there are problems and questions that cannot be discussed in our classrooms, but there ought to be a fearless, frank, clean method of looking at some of the common and sacred facts of life.

It may be said that thorough, fundamental physiological training should be given at home, but unfortunately parental influence is not unmixed blessing. In this present day parents, so far as indicated by practice, often seem as ignorant of the fundamental purposes, processes, and laws of life as are their children, and the training of the child to make a good citizen is left to the

teacher, altogether too often without parental coöperation. Whatever physiological instruction the child receives must be given in school. Obviously physiological and hygienic instruction of some kind should be given in all the grades of the school course from the kindergarten up, but it seems to me that nowhere short of the high school can this instruction be made a fitting preparation for intelligent citizenship. To leave physiology out of the high school curriculum is, it seems to me, an inexcusable blunder.

It will be admitted freely that the teaching of physiology in our high schools is in a very unsatisfactory state, but we may inquire: What high school makes any especial provision for physiological teaching? In what high school is physiology considered as coordinate in intrinsic value with mathematics, Latin, or even botany? How many high schools require a teacher who has specialized in the study of physiology? Have we not here one very potent cause of the ill repute into which this most important study has fallen? Teachers, who are worth anything, do not care to attempt to teach a subject for which they have made no especial preparation.

The policy of the national W. C T. U. in practically dictating the subject matter and arrangement of the same relative to the effects of alcohol, tobacco, etc., upon the human body, in all text-books of physiology for the public schools, on penalty of public disapproval and in consequence failure to sell, has had a blasting effect upon individual initiative in attempting to present the latest unbiased truths of physiology and hygiene. The man who writes a text-book on physiology so that it may be indorsed by any unscientific autocrat must have either little self-respect or a great deal of presumption. Let the expert in physiological research and methods state the facts as honest truth-seeking sees them; we need have little fear as to the results. It is the suppression and distortion of truth to bolster up a propaganda that does the harm. Sincerity is the avenue to the respect and confidence of a child. You cannot strengthen a child's character by telling him lies, however good your intentions. What is the honest teacher to do in regard to using one of these indorsed physiologies? What he does do is to let it alone as far as possible. The result is that a most fascinating subject is hated by both pupil and teacher. Not long ago I heard a prominent high school principal advise his fellow teachers to drop physiology in name from the

curriculum of the high school, and under the guise of biology, or botany, or domestic science, give some genuine physiological instruction.

The old text-book of anatomy, called a physiology, must give way to one constructed on a rational basis. Physiology must be taught as a live subject, of vital importance, of direct value to the pupil. It must deal with facts of general observation and of common knowledge. It must bring home to our comprehension the of the intricate chemical and physical operations that continually seemingly trifling details of everyday life and force us to see their importance. It must teach us the beauty and the significance go on in our bodies. It must show us that we live by law and not by chance. It must tell us how to avoid disease, accident, pestilence.

But the chief barrier to excellent teaching in physiology is the poor teacher. As long as the training of the mind is divorced from the training of the body, so long we may expect physiological teaching to be undervalued. Let us first give this subject its proper value; then the teacher will be found to fill the place properly.

The position of teacher of physiology in a high school demands by way of preparation thorough training in human and comparative anatomy; a fundamental, first-hand knowledge of fundamental physiological processes, such as the chemistry of digestion, the mechanics of the circulation, the processes involved in respiration and nervous activity. It may not be advisable for the teacher to introduce laboratory work in physiology into the high school, but he must have a knowledge of experimental physiology himself. He must understand sanitation, for the physiology of the future must ally with itself a study of the proper relation of the individual to his environment. He must know as much of hygiene as of anatomy, for in the future we must emphasize the safe-guarding of the individual, prevention rather than cure.

Is it too much to ask for such preparation? Our teachers of Latin must study that language from three to seven years before we consider them fit instructors for a high school. German, English, mathematics, all require many years of preparation. Should not the teachers of natural science, who are likely to give the physiological instruction, have spent years, instead of weeks, in preparation?

OPPORTUNITIES FOR YOUNG MEN IN BOTANY.[1]

By John G. Coulter,
Illinois State Normal School.

Some of us have been assured by those who have arranged the program that the sharers in this symposium are not to feel themselves fettered by the specific limitations of their assigned topics. Hence my liberty in asking first why we should be concerned at all in any special effort to increase interest in science work as a profession. General public interest in science is another matter. The aim of this symposium, however, appears to be to point out why a choice of their life work from the various branches of science is a desirable choice for young men to make.

It may be reasonably inferred, if only from the remarks made in the discussion of the dues of this organization, so happily placed at one dollar, that we have nothing very great in the way of financial compensation to offer. For that very reason, if we are good economists, should we not be the last to encourage more strenuous competition for the few real competences which exist for the sustenance of our life-workers ? Yet here we are most cheerfully engaged in doing that very thing. Though there may be far from enough to go around in generous portions, let us by all means have more in at the feast. There may be compensation in the extra-prandial proceedings.

An editorial in a recent science periodical presents the estimate that fewer than five thousand persons in the United States are professionally engaged in science investigation or in the teaching of science up to the research point. Of these it reckons that fewer than one thousand should be counted real contributors. What are one thousand among eighty million? We must accept it as a fact that several European nations excel us in this respect.

But it comes to mind that our inferiority herein may be due as much to absence in the minds of the educated public of definite knowledge of the aims and actual work being done in science progress as to anything else. Herein is perhaps the best reason for such a symposium and for such an organization as has just been perfected. These words of Matthew Arnold seem appropriate:

"The great men of culture are those who have had a passion for diffusing, for making prevail, for carrying from one end of

[1] A part of the symposium on opportunities for young men in science at the organization meeting of the Illinois State Academy of Science at Springfield, December, 1907.

society to the other, the best knowledge, the best ideas of their time; who have labored to divest knowledge of all that was harsh, uncouth, difficult, abstract, professional, exclusive; to humanize it, to make it efficient outside the clique of the cultivated and learned."

The point is then that our real science workers are both too few and too remote from the general public. They work very largely in another world than the one of common conception. From the world of common knowledge they must, perhaps always, remain aloof. But may not the real value of their work be at least adequately conceived? In Europe the magazines and even the shop windows furnish evidence of the popular interest in science progress. Wherever the forward movement is most active you catch a quick reflection of it in the popular press. There the public is said to be really much concerned of late with what is sometimes called the "passing of Darwinism." What does the American public know or seriously care about Darwinism being on its "deathbed"? Here our editors shun the rather dry and obscure authorities in favor of picturesquely-worded and sensation-charged celebrities; and, reciprocally, for fear of their brethren, the authorities shun the editors.

Yet are we not ready to admit that the modern aspect of national progress, as ordinarily conceived, depends very largely upon the number of properly qualified persons who are engaged in science research, and, perhaps quite as much, upon the extent to which the general public follows their advance? Does not the fault for this large American gap between science workers and the general public lie much with the scientists who have held aloof; who have but rarely taken it as part of their task properly to popularize the problems on which they are at work; who have let misrepresentation go almost unchecked and have made something of a jest of public misinformation; who have done much to form a sort of exclusive aristocracy of their own kind?

But, wherever the fault lies, we must lessen the gap. The constitution we have just adopted explicitly commits us to this. Unless there develops more popular interest in the great truth search, in this and its many other aspects; unless there develops more feeling of personal responsibility in finding out for one's own self by the methods of science, and less of easy acceptance of the first plausible explanation, then the national peril for lack of "clean truth" to which Dr. Chamberlin made reference this

morning is surely not very difficult to perceive; a reference which, by the way, has some responsibility for this digression from my immediate topic. * * * *

Specifically, of the opportunities in botany, we can say that the demand for trained botanists continues to exceed the supply. Such demand is of course especially for young men ready to begin their service at compensation less than the theoretical value of the service rendered. Further, it is almost exclusively a demand for men to whom the service means at least as much as the compensation. But, as such, it is unquestionably a vigorous and growing demand.

The most extensive employer of young botanists in America is the United States Government, and we are very reliably informed that the various bureaus of the Department of Agriculture are in positive need of more men adequately trained in plant morphology and physiology than they can find. Such training is usually sufficiently well attained in two or at most three years of graduate study.

It is becoming increasingly difficult to differentiate between botanists pure and simple and special students of scientific agriculture. Yet we are loath to lose good men through a mere juggling of terms, such as botanist into agronomist or something like, even though the latter title cashes in better. So, among present day opportunities in botany, should not be overlooked the one of being botanist in fact only, with sedulous avoidance of a name which contains no hint of the large cash values upon which this section of the profession, under its many aliases, may justly pride itself.

For teachers of botany the market is still brisk, though the upward tendency is not perhaps so marked as in other lines of demand. Doctors of philosophy in botany are commanding beginning salaries in teaching positions which average about fifty per cent more than those offered eight years ago. These are in the main positions of collegiate or equivalent educational rank. It is for teachers of lesser training that the demand has shown a barely perceptible falling off. But this is more than offset by the increasing demand for teachers of agriculture for the rural high schools. What botany in some quarters is threatened with losing as a high-school subject, agriculture has already more than gained. Since the question is very largely one of teaching

much the same subject in a more efficient way we may expect that botany, in this respect, will be a graceful loser.

In the Philippines a "practical" botanist is wanted in every province, of which there are more than thirty, to take in charge the immensely important educational side of the problem, especially from the standpoint of the agricultural possibilities. No stereotyped problem here, nor meager compensation therewith.

The opportunities for amateur work in connection with the Academy should perhaps receive a word of comment. Apart from its large educational function, I take it that the contributory work of the Academy will confine itself in the main within state boundaries. With such limitation, and assuming the coöperation of a considerable and favorably distributed number of capable persons, an ecologically annotated geographic catalogue is the first task which suggests itself. Such work has for such an organization the peculiar virtue of comparative simplicity in its individual parts, absolute necessity for extensive coöperation, and the very large value of the final symposium. The humblest sharer in the work may be thoroughly satisfied that his part is quite as important as almost any other part.

Of intensive area work in ecology Cowles's work on the dunes and Gleason's recent study of the sand flat areas of the Illinois river forcefully suggest the considerable number of similar, yet untouched, and equally attractive problems within the State.

The native prairie plants, made historic by their striking floral aspects alone, remain undisturbed in but few and restricted areas. The salvation of a strip of native prairie large enough to reveal the original ecological factors may be beyond us, but the Academy may well have in mind a State Garden of the native plants.

Fresh acres in garden and field will be given each year to the new experiments in plant breeding, and the amateur may lend a hand, though our agronomical friends may challenge the pertinence of such a suggestion among points for amateur *botanists*.

* * *

For a somewhat more definite suggestion in closing I must again seek excuse in that incontestable statement of our president this morning that in lack of clean truth there lies national peril.

Nowhere in our educational literature is the absence of clean truth more conspicuous than in the nature study books which are in common use in our graded schools. Nowhere has the unauthorized word had wider play or more credulous following.

Untrained teachers have had nature study thrust upon them and have turned with avidity toward whatever seemed to offer help. Composites of sentiment and inaccuracy have been liberally supplied as "supplementary reading."

The suggestion just referred to is that there be issued in the name and under the direct auspices of the Academy a series of leaflets upon science topics suitable for use as material in nature study and geography. Such topics should be treated especially from the standpoint of the State of Illinois in so far as they lend themselves suitably to such treatment. Such leaflets should be available to the public schools at low cost. An educational editor, perhaps a member of the standing committee upon publiciation, might have in charge the apportionment of topics to members willing to coöperate, and ample discretion in editing to suit the educational needs in view should be allowed such an editor.

In objection it may be urged that in its very infancy the Academy would be rash to venture to finance such a scheme. It may be confidently stated, however, that funds sufficient for such purpose would be at the disposal of the Academy in case such proposal meets its good will.

A similar service has been and continues to be rendered by the Cornell Nature Study and Agricultural Leaflets.

WHAT'S THE USE OF BOTANY?

By Willard N. Clute.

The question that stands at the head of this article is the one I hear most frequently aimed at those who are taking, or who contemplate taking, a course of botany in the high school. Too long concerned with leisurely jaunts about the country in search of "specimens" and the pulling of flowers to pieces in order to "analyze" them, botany has come to be viewed by many with a sort of amused contempt which has found expression in the quip that "botany, like croquet, is a fitting pursuit for elderly ladies and ministers." The boy who elects botany, or the man who teaches it, is regarded by the community as having a feminine streak somewhere in his make-up, no matter what other good qualities he may possess. In consequence, botany classes consist largely of girls. With the occasional exception of some clear-headed individual who knows exactly what he wants and goes in for it, the more vigorous and ambitious boys avoid such a

course as boys of their age avoid all things feminine. The result is that the men of our country are being graduated from school and college with no knowledge of plants, no understanding of the mission of parks, conservatories and the like, no idea of the value of outdoor life, no appreciation of nature—in short, entirely lacking in that form of culture which should yield them some of the choicest and most lasting pleasures of their lives.

Linnaeus, "the father of botany," called this "the amiable science," and amiable it is to all who understand it aright, but the understanding comes only from long familiarity with it. The boy bent on selecting that course which will enable him to become a millionaire in the shortest space of time must have something more concrete than pleasures of the mind to entice him to take up the subject. In chemistry, physics, mathematics and the like, he sees the beginnings of an equipment for earning a living and he even looks with favor upon Spanish, French and German since they may possibly help, but botany—if useful at all, good only for raising vegetables. And "who wants to be a farmer?" Farming, however, is only one phase of botany, applied botany. The boy who scorns to be a farmer, and many an adult of like mind, fails to perceive that this is not all of botany; that after the getting of a living, no matter by what means, there is still the living of it and that the man who has only gainful things to spend his leisure upon has no true leisure to spend and few enjoyments beyond the making of more money.

What, then, can the teacher say that will convince not only the boy, but the boy's parents and even the members of the school board that the study of botany is one of prime importance? In my opinion, there is much that can be said. Botany need not be introduced into the high school in the expectation of making either botanists or farmers of its students, but for the correct ideas of plant life which it should give. This science together with zoölogy and physiography is our chief source of information of the world about us; that world with which we strive for our very existence, and striving with which, we have become what we are. No matter how learned a man may be in the languages, no matter how eminent in mathematics, no matter how skilled in the physical sciences, he is still an incomplete and lopsided individual if he is not also familiar with the earth, the animals and the plants. This alone is sufficient reason for requiring every boy and girl in the high school to take botany, but

it is not the only reason. If the science is properly taught there is not a subject in the whole curriculum that is so conducive to the development of the pupils' powers of observation, comparison and deduction—powers which require to be highly developed for any real success in this world.

Nor is the fund of knowledge about plant life which one gains from botany to be lightly regarded. The farmer is not the only one who grows plants, or has need for such knowledge. Most of us, I fancy, have a garden, or a flower bed, or a window box, or a potted plant or at least a bunch of flowers, now and again, and having them must know how to maintain them in good condition. No florist was the poorer florist for being a good botanist, no minister less eloquent, no lawyer less convincing, no physician less skillful. As for the farmer, the forester and all who have to do with the products of the soil, the better botanists they are the better shall we be fed and clothed and housed.

Leaving these more practical aspects of the case, we may turn to others none the less important because not measured in dollars and cents. The literature of every land abounds in references to nature that can be appreciated only by one familiar with botany. All others who read, miss half the beauties of the text. It is the same with the fisherman, the hunter, the camper, the boatman and all who love the outdoor life—to be unacquainted with plants is to fail to reap the full pleasures of existence. In itself, botany takes its votaries into the open air, across field and wood, from valley to mountain top, ever new, ever beautiful, ever attractive. It makes companionship in strange places, peoples the wastes and solitudes with friends, keeps the mind from stagnation and is the source of constant delight renewed as often as the seasons change.

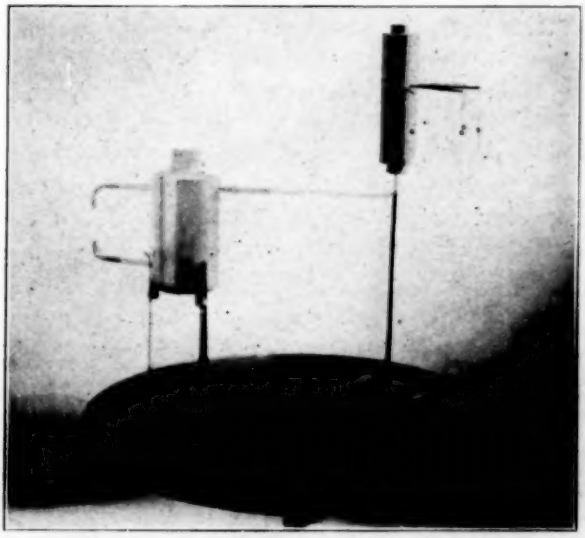
The Cambridge Botanical Supply Co., after twenty-four years catering to the botanists and physiologists, have, in reply to the appeals of many physicists, issued a catalogue of physical apparatus. The catalogue contains quite a few novel and useful pieces of apparatus, at prices within the reach of every school. It has three sections, magnetism, static electricity, current electricity, with several pages of miscellaneous apparatus. Every physics teacher should have a copy.

A SIMPLE CONDUCTOMETER.

By John F. Bonnell,
Emory College, Oxford, Ga.

The engraving is from the photograph of an easily made conductometer for lecture use.

The solids used are rods of silver, copper, iron, brass and aluminum, thrust through holes bored in an oak tube, all in one plane, and nearly meeting in an arc inside the tube. They are each about 10cm. long.



The oak tube may be 20cm. long, 5cm. diameter, with bore 2.5cm., and closed at the ends with rubber stoppers, one at the top perforated to receive a bent glass tube. The lower stopper has two holes, one for mounting the wooden tube on the rod of a ringstand, the other for a bent glass tube to connect with an ordinary laboratory boiler.

The five metal rods sustain at their outer ends bullets, hung by short threads which are stuck on the rods with the least bits of paraffine.

From the boiler steam is driven through the oak tube, imparting heat to the metals rapidly and uniformly, and as the heat reaches the outer ends of the rods, it melts the paraffine and the bullets drop off in the order of conductivity of the metals.

This device is found to be an improvement on the old conductometer of Ingenhaus, since by employing steam heat the action is certain and speedy.

A DEMONSTRATION EXPERIMENT ON THE SUB-COOLING OF WATER.

By N. F. Smith,

Olivet College, Olivet, Mich.

The sub-cooling and subsequent freezing of water is an experiment which always arouses great interest on the part of the student, but as ordinarily performed it is a matter of some trouble and more uncertainty, since the water has a habit of often freezing at 0° instead of remaining in the liquid form at a lower temperature. The following method has proved all that could be desired of a demonstration experiment:

A glass bulb from one to two inches in diameter having a stem attached is half filled with distilled water. The water is thoroughly boiled to expel the air and the stem is sealed off, leaving the bulb filled only with water and water vapor. The bulb may now be placed in a freezing mixture of salt, ice, and water, whose temperature is ten degrees below zero and allowed to remain indefinitely without danger of freezing. On removing the bulb and giving it a sudden shake the water is instantly transformed to a mass of ice. The bulb, when once prepared, is always ready for use, and the experiment can be shown to a class in a moment and repeated several times if desired by simply warming the bulb till the last trace of ice is melted. The experiment is readily adapted to projection in the lantern.

For those who have not had experience in sealing a bulb filled with water vapor, the following statement of the writer's method may be helpful: Before the water is placed in the bulb, the stem is drawn down at one point to an inside diameter of a millimeter or less. A glass stop cock is sealed to the end of the stem. Instead of this, a piece of soft rubber tubing tightly wired on, which may be closed by a pinch-cock may be used. While the water in the bulb is boiling vigorously the stem is closed by turning the stop-cock or compressing the rubber tubing. The bulb is allowed to cool to room temperature. The possibility of leakage at this stage is avoided by inverting bulb so that the stop-cock is under pure water. After the bulb has cooled, the stem may be sealed off at the narrow part and the bulb is ready for use.

STATE GEOLOGICAL SURVEY REPORTS ON LIMITED AREAS.

By Frank Carney,

Denison University, Granville, Ohio.

Now perhaps as never before men in the service of the people are considering values. As trustees of money raised by taxation they are zealous of making their expenditures count. The funds paid out by municipalities, states, and the nation are being scrutinized for the needless or the careless. This concern for money that belongs to no particular individual, but to society, is indeed of fairly recent development. Applying to the affairs of government the methods that have made possible some of our great industrial combinations it is found that the leaks hitherto unrecognized may be checked, and that investments which casually seem to yield proper returns, when *examined closely*, are found unprofitable.

But industrialism or the spirit of commercial exploitation, neither through example nor direct influence, can be said at present to hamper the purely scientific or theoretical side of investigation. The sums of money contributed by individuals for the prosecution of specific problems, or for the endowment of continuous research, is without parallel in any civilization of which we know. Indeed, the terms of some of these endowments are so elastic that their disbursement may become quite as onerous a task as their original acquirement. To make the best use of funds, however, is a problem with trustees in charge of endowments, and with officials who direct the expenditures of the people's money appropriated to survey work.

The files of some of the older reports of both state and national surveys when analyzed from our present view-point certainly contain not a little material that the science would scarcely feel the loss of; possibly, too, the comment might to some extent fit publications of even later date. To be sure, there was a time when reconnaissance work was necessary; but the methods and the results of such work in any field of investigation have no excuse for reaching beyond the early stages of the research. To about the same category of uselessness belongs the duplication of results that we observe in the publishing of the same investigation, in part or entire, in two or more organs. It is not suggested that preliminary notices of later and more extended work have no field. The purport of the comment bears upon the need-

less duplication of sources that the reader or student has to use in seeking information, and in tracing down or compiling bibliographies. While the tendency here mentioned does not concern workers in the employ of surveys, to the exclusion of others, nevertheless it is a fair question whether the avenues of publication afforded by surveys should not be the only source of much information which we may find, sometimes more or less attenuated, in the current magazines.

But pioneer work has no further place in the more thickly settled parts of our country. Geological reports at the present time in the main conform to a carefully worked out policy, one part of which reflects, or should reflect, the conditions and needs of the area being studied. This policy should be elastic enough to meet the unforseen exigencies as the field work progresses. Seldom can a campaign of investigation be so minutely sketched in anticipation of the work in the field that variations are not only necessary but usually wise. The point to be emphasized is that while work of the reconnaissance type has to construct its own methods largely as results accumulate, the modus operandi of survey work to-day plots the ground before breaking it.

The details of such a policy naturally group themselves into two divisions: (1) Scientific, or contributions to knowledge; (2) Those that comply with the requirements of popular use, or that are intended to cultivate further uses by the public.

AS A CONTRIBUTION TO KNOWLEDGE.

The major part of the work that has been fostered by our surveys is comprised in this division. The several state surveys in their genesis were doubtless concerned more with that which might bring the commonwealth into the utilization of valuable natural resources before unknown or unexploited; thus the work by these surveys contributed to knowledge. The utilitarian aspect of such contributions, however, soon places them in the other division. Hence the line of cleavage between the theoretically scientific and the industrial or commercial is not permanent nor is it always clear. Furthermore, a restudy or reconsideration of an area may extend lines of knowledge already defined, or may open up new fields. It is apparent, therefore, that the work of surveys generally adds to the sum total of knowledge.

With the zeal that all our surveys have for investigation there is little need of discussion. The purpose of this paper is merely

to emphasize one or two points along which the research may give more particular emphasis.

Maps.—The government topographic sheets should be used as the base for all work. We appreciate the fact that only a fraction of the United States has been thus mapped; therefore the curtailment of fields for work is evident. Nevertheless it is felt that only imperative economic or industrial demands should warrant expenditure of state funds in unmapped areas. The coöperation which our states can enter into with the Federal Survey makes it possible to push the production of sheets so that the activities of ordinary state survey work, outside of the strictly economic, may be given such range as state geologists desire.

We would urge the advantages of expressing, wherever possible, the results of field investigation in maps. The convenience of their use and the more concise statement of results makes it not only advisable, but an inducement to the investigator as well, to embody his findings, as far as practicable, in a map. It is noted, furthermore, that a map recital of facts may be more exacting in the character of the work done by the investigator, and it certainly demands of him greater comprehensiveness. The scale of the map, to be sure, admits of some indefiniteness, but this may be preferred to the generalizations that are possible in extended texts. The text part of reports may well be compressed that more funds may be available for producing maps.

Sedimentation.—Stratigraphical units which embrace only lithological distinctions are accurate enough for areas of crystalline rocks. Such units of definition may be applied also to sedimentary rocks, but this should be regarded as a secondary method of classification. The faunal content which accompany particular conditions of sedimentation should form a basis of stratigraphical maps. We have need, likewise, of maps which delineate the several phases of sedimentation.

The difficulties of showing in detail the sediments involved in some areas are obvious. Outcrops are few and disconnected; well records are often scattered and inaccurate or wanting. Not infrequently wide areas are completely buried beneath drift, or the products of residual decay. Whatever may be the conditions, the field study should be most thorough even to the extent of showing the impossibility of adducing any facts bearing in the stratigraphy. When the attitude of rock formations, or when river erosion, or both combined, have produced outliers, we have

the most favorable condition for obtaining the desired details of sedimentation. Areas of this type are common enough in most states to afford opportunity for exemplifying this phase of mapping sedimentary rocks.

An effort should be made to interpret rock formations from the view-point of present day sedimentation processes. The work that is being done by streams, by currents, by tides, represents the processes involved in producing and distributing the sediments which have become rock formations. To read into outcrops the various history of sedimentation is perhaps one of the tasks that has not appealed sufficiently to geologists.

Barrell[1] has recently published a theoretical discussion of sedimentation which affords workers a standard for the consideration of this topic. While it may not be practicable to attempt an interpretation of all sedimentary rocks in accordance with Barrell's standard, nevertheless it is felt that an effort, if but partially successful, would contribute much to this phase of Geology. The matter of irregularity of sediments as furnishing a criterion for discriminating between marine and continental deposits may most obviously be applied to an areal study of regions of such formations. A more exacting interpretation of the clastic sediments may with profit be insisted upon. Geologists customarily describe most sedimentary rocks as the product of deposits laid down in the ocean and seas surrounding the land areas. The part played by continental sedimentation has made but little appeal to writers. The force of this neglected side of the subject, Barrel makes evident. Furthermore, the writings of Huntington, Hedin, and other recent explorers in the arid sections of present land areas tend to impress upon us another neglected phase of sedimentation.

It does not seem beyond the capacity of even the student of the subject to appreciate, comprehend, and judiciously interpret the various phases of sedimentation that he may find illustrated in rock outcrops. The step from the great deltas of some of the rivers active to-day to the rock formations which represent the deposits of great rivers of the past, when once comprehended, is a marked progress in the appreciation of geological causes and consequences. This aspect of the subject may be made more important in the matter of high school earth science studies.

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[1] Joseph Barrell, *Journal of Geology*., vol. xiv (1906), pp. 316-356; 430-457; 524-568.

We would also emphasize the bearing that the fauna has in the question of sedimentation. The necessity of knowing whether deposits are marine, or fresh water, or neither, imposes upon the investigator an examination of the fossil content of these formations, or at least the necessity of establishing the fact that the formations are barren of life; and if barren, he should make such an investigation of the material which has entered into the deposits as may enable him to suggest reasons for an environment unfavorable to the development of a faunal facies.

The tendency of physiographers sometimes is to neglect the control exercised by rock terranes. The physiographic ecects due to variations in sediments perhaps in no case have been completely masked by deformations resulting from orogenic or other cause, although the impetus given certain drainage lines by an areal tilting not infrequently has rendered less obvious this control. In ultimate analysis, however, we find that streams rarely ignore the control due to the fact that many rock formations vary in hardness frequently along both horizontal and vertical lines.

THE DEMANDS OF THE PUBLIC.

All survey work is the result of a voluntary, or of a stimulated desire expressed by the representatives of the voters. The stimulation may have come from individuals, private or corporate, who are actuated by industrial motives, or it may be the effort of schoolmen and investigators actuated by more catholic incentives. The history of the organization as well as of the neglect of several state surveys show the pertinency of this assertion. The earliest records of some surveys may not disclose an economic or industrial impetus; possibly the constituencies of these surveys counted on more practical results than they obtained. Much that is purely scientific must always precede the practical. Nevertheless the reëstablishment of surveys in states where the original organization was not sustained usually gave emphasis only to the commercial or industrial factor.

Economic.—The discovery and examination of natural resources must always be foremost in the service rendered by surveys. The survey that neglects this aspect of its work is no more loyal to its trust than is the survey that devotes itself entirely to the immediate sources of material wealth. Recurrent economic reports in the absence of all other lines of publication can be excused only when the material interest of its clientage is, for the

time being, tantamount, or when any different course would jeopardize the survey's existence. When the territory of a survey has been shown, on progressively accumulated evidence, to be negative in natural wealth, its reports must needs deal with the purely non-commercial scientific lines of investigation. A series of such reports would be conclusive evidence either that the particular commonwealth was not controlled by sordid motives, or of a rare personnel in its survey. Naturally and rightly the commercial or economic phases of the people's geologic work is first.

State surveys and public schools.—We note that recently two state geologists, Clark[2] and Leonard[3], have called attention to the service that the state surveys may render the public school system. No state bureau is in a position to give so much authoritative information along lines that bear directly on the question of physiography as can the geological survey. It does not seem like overstating the fact to urge that this is a sphere of usefulness that our state organizations have either been unmindful of or have neglected. The matter of supplying information on the various phases of earth science has been left to the writers of general text-books on the subject. These general text-books, however, rarely fit specific localities. In no line of science is the practicability of concrete illustration more easy of accomplishment than in the field of study that does or should accompany both geology and physiography in the high school courses.

It must be admitted that the reports prepared for surveys by workers in particular fields are in most cases highly specialized contributions to some line of investigation. In other words, very frequently the specialist consciously prepares a report for a rather limited list of readers. It is obvious that such reports may not be of highest value either to the student or teacher in our schools. The question that presents itself, then, is whether it may not be wise to prepare supplementary reports that bear directly on the teaching possibilities of certain limited localities. These localities should be selected where a given expenditure will accomplish the largest results. Essentially, then, the matter is one of working up in detail for teaching purposes reports upon areas neighboring regions that are most thickly populated. It is not urged that such reports should be teaching manuals or

[2] W. B. Clark, *Economic Geology*, Vol. 1 (1906), p. 492, 496.
[3] A. G. Leonard, *Economic Geology*, Vol. 1 (1906) p. 570.

guides for field study; they may be so prepared as to show that the writer has in mind this particular class of readers. The reports need not be so specialized on the educational side as to lose general value. Typical conditions exist in some areas that are not of particular application to others; nevertheless the usual abundance of material provides ample opportunity for selection.

We would enumerate some particular lines along which our state surveys may be of greater aid to the public school. (1) The industrial or economic aspect of every locality should be made to come nearest the experience of students. Thickly populated centers generally imply a localization of industries. In so far as these industries are connected with the natural resources of the immediate region they are legitimate subjects about which information may be centered in the preparation of geological reports. If the region contains deposits of clay, or other minerals, their genesis and methods of handling the raw material may enter most pertinently into such reports. If the converting of some of the natural resources into a manufactured article necessitates the importation of other natural products, then the plant itself, as well as the pit or mine, should be made a subject of study.

(2) Since the usual phases of field work in practically all high schools now forms a part of the regular study of physiography and geology, discussion here is useless. There is no objection, however, to the survey ascertaining the extent to which local teachers are availing themselves of type illustrations afforded by the region. Possibly the more detailed study made by the survey may reveal unused opportunities of making these lines of earth science more concrete. It is very certain that the survey can prepare maps which would facilitate an easier, if not better, comprehension of local physiography and geology.

(3) In nearly all the more thickly populated centers citizens interested in science and history have organized societies which in many cases have become prominent through generous endowment. These local organizations have usually inspired investigation of more or less value, and have published it. Through exchanges with other learned societies a wealth of material is being accumulated. Where a library is maintained the use of this material may be general; and yet it is the experience of the writer that the schools do not always avail themselves of it. Our surveys by preparing and publishing bibliographies in their reports may aid in bringing the schools of such centers to a con-

sciousness of the material available. This plan would result in greater use being made of these aids, and, if the bibliographies are more complete, the libraries would doubtless be moved to make their list of references even more extensive.

(4) We would urge still another method of bringing state bureaus into a more useful relationship to the public schools, a method that has long been practiced in New York state where the department of public instruction has instituted a system by which lantern slides are loaned to schools. It is within the province of state geological surveys to be of great service to the school system in providing photographs and slides of physiographic and geologic phenomena[4]. The survey in the prosecution of its work assembles photographs, but their usefulness is usually limited to the readers of the reports. It is evident that this method would insure a service which at present the state surveys do not render. No official bureau is apt to become less efficient in making itself more useful. A service rendered to the public schools is the speediest method of doing the most good to the greatest number. It may be urged that the state geological surveys are not instituted for doing work of a character that most states have legally relegated to another bureau. This suggestion has no weight until the state departments of public instruction have expressed an unwillingness to receive from our geological surveys the coöperation mentioned.

A SATURDAY COURSE IN PHYSICAL CHEMISTRY FOR TEACHERS.

By Augustus Klock,

High School, Beverly, Mass.

Secretary of the New England Association of Chemistry Teachers

During the winter of 1907-08, a Saturday course in physical chemistry for teachers has been given at the Massachusetts Institute of Technology, Boston, in the Teachers' School of Science. This course was established and given, free of charge, by Mr. A. Lawrence Lowell, of Boston, who has charge of the funds of the Lowell Institute. The course, which was planned especially for

[4]The efficiency of "loan collections" in a city has been explained in a recent paper by Jane Perry Cook: *v. School Science and Mathematics*, Vol. VII (1907), pp. 451-456.

teachers of elementary chemistry, was conducted by Professor Gilbert Newton Lewis of the Research Laboratory of Physical Chemistry, Massachusetts Institute of Technology.

Fifteen lectures on the fundamental principles of physical chemistry made up the course, each lecture lasting an hour and a quarter, and followed by an informal discussion of the topic of the day. Throughout the course, Professor Lewis gave especial attention to those principles that are immediately applicable in elementary science; and he illustrated his lectures by experiments, many of which are adapted for use in elementary chemistry courses.

Among the topics discussed were the following:

Fundamental laws of matter and energy, the perfect gas, the transition from gas to liquid, liquids and solids, solutions, chemical equilibrium, thermochemistry, electrochemistry, and photochemistry.

Physical chemistry, the subject treated in this series of lectures, was selected by a postal card vote of the members of the New England Association of Chemistry Teachers as a result of a canvass made by the secretary in the spring of 1907. That the selection was a wise one is evidenced by the fact that the course maintained until the end a membership of about sixty teachers of chemistry.

It was recognized by teachers in general that physical chemistry is, at the present time, in a period of great activity, bringing out at frequent intervals new explanations for phenomena that form the essential part of elementary chemistry; and while many of the older teachers had never had the opportunity to take this subject while they were in college because the newer theories of physical chemistry were not then taught in college, many of the younger teachers who had taken such courses in college found this course an excellent opportunity to review the subject and receive a more up-to-date presentation of it.

To illustrate the general character of the course Professor Lewis has written out in full one lecture, which appears in another part of this issue of SCHOOL SCIENCE AND MATHEMATICS. Professor Lewis has, moreover, promised to publish the lectures in book form soon.

The giving of this course under the auspices of the New England Association of Chemistry Teachers has proved so successful that this Association has already under way a movement to secure a course in industrial chemistry for the coming winter.

THE IONIC THEORY.[1]

By Gilbert Newton Lewis,
Massachusetts Institute of Technology.

In the previous lecture we have seen that certain substances dissolved in water show an abnormal behavior. These substances are the so-called *electrolytes,* namely, the salts, the acids and the bases. On theoretical grounds we should expect one mol[2] of any substance, when dissolved in 10 liters of water, to lower the freezing point by .186°. We find indeed that in this quantity of water a mol of alcohol lowers the freezing point by .186°, a mol of sugar .187°, a mol of glycerine .186°, but a mol of sodium chloride lowers the freezing point .348° and a mol of nitric acid .353°. In other words these two substances lower the freezing point of water nearly twice as much as the normal substances do.

The simplest explanation of this striking phenomenon is to assume that the sodium chloride and the nitric acid really form more mols in solution than correspond to the common formulas NaCl and HNO_3.

We have already used a similar explanation to account for the abnormal behavior of certain gases. If we calculate the volume occupied at a given pressure by a given amount of nitrogen peroxide on the assumption that the formula of the gas is N_2O_4, we find that the volume thus calculated is smaller than the one actually occupied by the gas. This is due to the partial dissociation of the N_2O_4 into NO_2, and since one mol of the former gives two mols of the latter the volume is increased.

Fig. 1

I have here a tube (Fig. 1) containing a mixture of the two forms in equilibrium with each other; the colorless N_2O_4, and the orange brown NO_2. Now when I dip the tube into hot water you will notice that the color deepens as more of the N_2O_4 dissociates. Now, on the other hand, when the lower end of the tube is dipped into cold water the color nearly disappears from this part of the tube owing to the reverse change from NO_2 to N_2O_4.

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[1] This is the fifth of a series of fifteen lectures on Physical Chemistry for Teachers given under the auspices of the Lowell Teacher's School of Science and the New England Association of Chemistry Teachers.

[2] A mol of a substance is the number of grams which equals the molecular weight. Thus a mol of Hydrogen (H_2) is 2 g., of Oxygen (O_2) 32 g., of sugar ($C_{12}H_{22}O_{11}$) 342 g., of alcohol (C_2H_5OH) 46 g., of glycerine ($C_3H_5O_3H_3$) 92 g., of hydrochloric acid (HCl) 36.5 g., etc.

If we assume likewise that sodium chloride dissociates when dissolved in water we are led to some very interesting conclusions, for according to our molecular conceptions there are not a large number of ways in which the molecule NaCl can break up into two molecules. In fact the only way that we can see consists in the separation of the sodium and the chlorine. In other words the assumption that sodium chloride dissociates in solution necessitates the conclusion that out of it two new substances are formed, one of which contains sodium but no chlorine, the other chlorine but no sodium. But our assumption leads to no further conclusions as to the nature of these new substances. They may, for example, both be hydrated (combined with water) and probably are, but we have seen in a previous lecture that there is at present no exact way of determining to what extent a dissolved substance may be combined chemically with the solvent.

This assumption of the dissociation of salts, acids and bases. when dissolved in water, is not at first sight extremely plausible, and I doubt if it would have been adopted if the argument in its favor rested solely upon the freezing point measurements, but the more we investigate the properties of the solutions the more evidence we find to support this view of dissociation.

Consider a solution of hydrochloric acid. What are its properties? It tastes sour, it turns litmus red, it dissolves metals, it converts sugar into a substance known as invert sugar, it dissolves certain carbonates, it turns yellow chromates into orange bichromates, and so on. But these properties are properties which all acids possess. The solution of hydrochloric acid has another group of properties. It produces white precipitates with silver nitrate or mercurous nitrate, but so does any other chloride (experiment with a series of chlorides). It has in other words one group of properties which all acids possess and one group which all chlorides possess, but not a single property which is peculiarly its own. It behaves as if it were a mixture of two substances, one of which is present in all acids, the other in all chlorides. What we have said of hydrochloric acid is true of many other acids, many bases, and practically all salts dissolved in water. It is not true in general of solutions in other common soevents, although in these there is often evidence of a certain amount of dissociation.

In these two flasks I have solutions in alcohol of cobalt nitrate and cobalt chloride containing approximately the same amounts

of cobalt. The first solution is red, the second blue. Now I will pour these two solutions into these two large jars containing equal quantities of water. First the nitrate, which gives a pink solution, now the chloride, which, as you see, gives a solution of precisely the same pink color, indistinguishable from the nitrate solution. In the two alcohol solutions there were apparently two different colored substances, but in the two water solutions only one colored substance present in both.

As in the case of the sodium chloride, cobalt chloride in aqueous solution seems to dissociate into two substances, of which one has a pink color and is present in the solutions of all cobalt salts, the other is colorless and present in all chlorides.

Here again are three copper salts, the nitrate, chloride, and bromide. In the solid state (with water of crystallization) they are blue, green, and brown, respectively. Here are three alcohol solutions containing approximately equivalent quantities of these substances. Their colors happen to be the same as those of the corresponding solids, being, in the same order, blue, green, and brown. I pour these now into these three large jars containing equal quantities of water. The resulting solutions are all light blue[3] and identical in appearance. Here again each salt appears to have dissociated into two substances, one of which is blue and common to all copper solutions.

Before proceeding to develop the further arguments for dissociation, it will be convenient to give a name to these substances which we believe to be formed in consequence of dissociation in aqueous solutions of salts, acids and bases. Following Faraday we will call them in general *ions* and the process of dissociation into ions we will call *ionization*. In particular that substance which is present in all acids we will call hydrogen ion; the one which is present in all bases, hydroxide ion; that which is in the chlorides, chloride ion. So similarly we may speak of sulphate ion, potassium ion, carbonate ion, ferrous ion, ferric ion, etc.

Obviously we may divide the ions into two classes as illustrated by the following table:

Hydrogen ion	Chloride ion
Sodium ion	Nitrate ion
Silver ion	Bromide ion
Ammonium ion	Hydroxide ion
Calcium ion	Sulphate ion

[3]The solutions may be slightly cloudy due to hydrolysis of the copper salts. This will be prevented by the addition of a trace of acid to the alcohol solutions.

Barium ion	Carbonate ion
Ferrous ion	Chromate ion
Aluminum ion	Phosphate ion
Ferric ion	

We notice that any ion in the left hand column may combine with any ion of the right hand column to form a substance of the type of acid, base, or salt. The first class we will call positive ions, the second class negative ions.

The ions of one class are not all alike in what we call valence, thus one mol of sodium ion combines with one of chloride ion, but a mol of calcium ion takes two mols of chloride ion, and a mol of aluminum ion takes three.

On these facts we base our ion notation, which expresses simultaneously the positive or negative character of the ion and its valence. The method of notation is sufficiently obvious from the following table which gives in order the symbols used for the substances of the previous table:

H^+	Cl^-
Na^+	NO_3^-
Ag^+	Br^-
NH_4^+	OH^-
Ca^{++}	SO_4^{--}
Ba^{++}	CO_3^{--}
Fe^{++}	CrO_4^{--}
Al^{+++}	PO_4^{---}
Fe^{+++}	

The process of ionization is expressed therefore by equations such as the following:

$$HCl = H^+ + Cl^-$$
$$NaOH = Na^+ + OH^-$$
$$Na_2SO_4 = 2\ Na^+ + SO_4^{--}$$
$$Ba(NO_3)_2 = Ba^{++} + 2\ NO_3^-$$
$$AlCl_3 = Al^{+++} + 3\ Cl^-$$

The above experiments with colored substances such as cobalt and copper salts are among the most obvious but not the most convincing evidences of ionization. The following experiments, when carefully considered, offer an even more striking argument:

Here I have what is called a Dewar vacuum tube, namely a double walled tube in which the space between the walls is exhausted, thus forming a very efficient insulating jacket[4]. Inside

[4]The vacuum tube may be replaced by a large test tube surrounded with cotton wool. The volume of the tube should be about 250 cc.

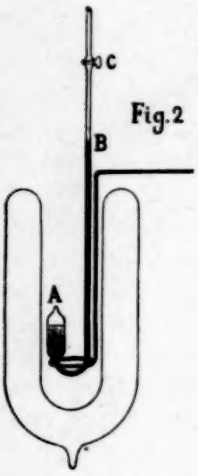

Fig. 2

the tube is t stirrer and a thermometer. The latter is shown in Fig. 2 and consists in a bulb A, of about 20 cc. capacity, the upper part of which contains sulphur dioxide gas and a layer of liquid sulphur dioxide, and the lower part contains mercury, which also fills the smaller connecting tube (3 mm. inside bore) as far as B. Between B and the closed stopcock C, there is air under a pressure of 3 to 4 atmospheres. A change in the temperature of A produces a change in the vapor pressure of the sulphur dioxide and thus causes a movement of the mercury meniscus at B. If the tube BC be given a length of 1 meter the meniscus at B will move several centimeters for every degree change of temperature in A.

In these flasks I have 100 cc each of normal solutions of potassium nitrate, sodium nitrate, potassium chloride, and sodium chloride, all at the temperature of the room[5]. I will now pour into the Dewar tube the solution of potassium nitrate and mark the position of the thermometer. Now I pour in also the solution of sodium chloride. You see there is no change in the position of the thermometer. This shows that no heat has been evolved or absorbed during the mixture of the two solutions. It has been found, however, that in nearly all cases where a chemical reaction occurs there is an evolution or absorption of heat, and our experiment indicates, therefore, that no reaction has occurred between the potassium nitrate and the sodium chloride.

Now we may empty the Dewar tube and repeat the experiment, using sodium nitrate and potassium chloride. Again we find no heat effect on mixing. Yet this mixture of sodium nitrate and potassium chloride can be shown to be in every respect identical with the mixture of potassium nitrate and sodium chloride.

This phenomenon has been found to be a very general one and has long been known as the law of the thermo-neutrality of salts. For over half a century it was one of the mysteries of chemistry, for, it was said, if there is a reaction when salts are mixed, why is there never any heat change? And if there is no reaction how can identical mixtures be obtained from KNO_3+NaCl and $NaNO_3+KCl$?

[5]The flasks containing the solutions used in this and the following experiment all stand in a flat pan of water in order that they may keep at the same temperature.

The solution of this problem is, of course, obvious when we admit ionization in solution, for then we see that the four solutions contain not (a) KNO_3 (b) $NaNO_3$ (c) KCl (d) NaCl but,

$$(a)\quad K^+ + NO_3^-$$
$$(b)\quad Na^+ + NO_3^-$$
$$(c)\quad K^+ + Cl^-$$
$$(d)\quad Na^+ + Cl^-$$

and mixtures of (a) and (d), and of (b) and (c) give without any chemical reaction the two identical mixtures,

$$(a) + (d);\ K^+ + NO_3^- + Na^+ + Cl^-$$
$$(b) + (c);\ K^+ + Cl^- + Na^+ + NO_3^-$$

In certain cases, however, we do find very considerable heat effects when two solutions are mixed, for example when an acid is mixed with a base. A study of such cases throws further light on the question of ionization.

It is pretty obvious that water itself is not to any large degree ionized. It does not, for example, taste sour as solutions do which contain hydrogen ion in considerable quantity. Neither does it show the alkaline properties which are characteristic of solutions which we believe contain hydroxide ion. In other words the reaction

$$H_2O = H^+ + OH^-$$

does not occur to any considerable extent, and therefore conversely we may expect that the opposite reaction

$$H^+ + OH^- = H_2O$$

will take place whenever solutions containing considerable amounts of hydrogen and hydroxide ion are brought together. This is in fact what occurs in the neutralization of an acid and base, as is strikingly shown in the following experiment: Here I have four flasks containing (a) sodium hydroxide, (b) hydrochloric acid, (c) potassium hydroxide, (d) nitric acid. I have taken 100 cc of each and all the solutions are of normal concentration, and all at the same temperature. In the Dewar tube containing the thermometer and stirrer I will first pour the sodium hydroxide and record the temperature. Now I add the hydrochloric acid. Instead of remaining constant as in the previous experiment you see that the temperature rises rapidly and on stirring comes in about one minute to a constant position 14 cm. higher than before. We will now mark this point, empty the tube, and repeat the experiment with the potassium hydroxide

and nitric acid. On account of the heating of thermometer and tube due to the previous experiment the temperature now starts a little higher, but on the addition of the nitric acid to the potassium hydroxide the rise of the thermometer is again 14 cm., precisely what it was when sodium hydroxide and nitric acid were mixed. Since the total heat capacity of the system is the same in both cases this means that the same amount of heat was developed in both reactions, which, according to the older style, would be written,

$$NaOH + HCl = NaCl + H_2O$$
$$KOH + HNO_3 = KNO_3 + H_2O$$

When so written it is not obvious why the same amount of heat should be evolved in both cases, but if we adopt the ionic conception we should regard all four of the original substances as already ionized and therefore mixtures of the following composition,

(*a*)	$Na^+ + OH^-$	(*c*)	$K^+ + OH^-$
(*b*)	$H^+ + Cl^-$	(*d*)	$H^+ + NO_3^-$

Moreover the salts resulting from the two reactions we must also regard as ionized. Hence we should write the two reactions as follows,

$$Na^+ + OH^- + H^+ + Cl^- = Na^+ + Cl^- + H_2O$$
$$K^+ + OH^- + H^+ + NO_3^- = K^+ + NO_3^- + H_2O$$

Now it is not customary to insert, in the equations representing chemical reactions, substances which are neither consumed nor produced by the reaction. We may therefore simplify the two equations by omitting all substances which appear on both sides of either equation. The result is that both equations are reduced to a single equation, namely

$$OH^- + H^+ = H_2O$$

In other words the heat evolved in the two reactions is identical because the reactions are identical. The neutralization of any typical acid and base consists merely in the combination of hydroxide ion and hydrogen ion to form un-ionized water.

By a similar experiment we may show and by similar reasoning explain the fact that the heat of precipitation of a given amount of silver chloride is in general the same, regardless of what silver salt or what chloride may be brought together to produce the precipitate. In any case the reaction is merely

$$Ag^+ + Cl^- = AgCl \text{ (solid)}$$

So far we have considered such acids, bases and salts as may for most purposes be regarded as completely dissociated in dilute solution. This class of substances, which includes practically all the salts, such acids as sulphuric, hydrochloric and nitric, and such bases as sodium and potassium hydroxides, we shall call strong electrolytes. Other substances which appear to experience similar ionization but only to a limited extent we shall call weak electrolytes. To this class belong, for example, acetic and carbonic acids and ammonium hydroxide.

Here I have solutions of hydrochloric and acetic acids. They are both of normal concentration and therefore capable of neutralizing equal quantities of alkali, as I may readily show you. In this burette I have a normal solution of sodium hydroxide. In this flask I will take with a pipette 25 cc of the hydrochloric acid and add a drop of phenol phthalein, which is colorless in acid solutions but red in alkaline. Now as I run into the flask the liquid from the burette you notice that the solution turns red when 25 cc of the alkali have been used. Taking again 25 cc of the acetic acid we find likewise that 25 cc of the alkali are required for its neutralization. Now I shall attempt to show you that although these two solutions are in this respect equivalent, the actual concentration of hydrogen ion in the acetic acid solution is very much smaller than in the hydrochloric acid solution, owing to the small degree of dissociation into ions which the acetic acid experiences.

Here I have each of these two acids in an upright tube inverted over a dish containing the same liquid.[6] (Fig. 3) Into both I will insert exactly similar rolls of magnesium ribbon. You will see that both acids act on the magnesium, but the hydrochloric acid much more violently. In this tube in a few minutes the acid is entirely replaced by the hydrogen evolved.

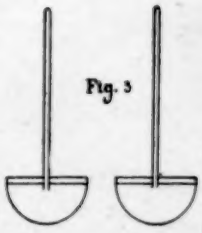
Fig. 3

Here I have three bottles containing normal hydrochloric, normal acetic and tenth normal hydrochloric acids. Into each of these bottles I shall pour, as nearly simultaneously as possible, equal quantities of a mixture containing potassium bromate, potassium iodide and a little starch paste. In the presence of acids the bromate acts upon the iodide to set free iodine thus

[6] The liquids may be colored by some organic dye to make the experiment more readily seen.

causing the starch to turn blue, and the rapidity of this reaction seems to depend upon the concentration of hydrogen ion. As I pour the solution into the bottles and shake, you see that the bottle containing normal hydrochloric acid turns blue almost instantaneously. In a few seconds the solution of tenth normal hydrochloric acid turns blue, and only at the end of several minutes does the acetic acid change color. This experiment indicates that the normal acetic acid has a smaller concentration of hydrogen ion than even the tenth normal hydrochloric acid. There are many other ways of illustrating the same fact, some of which we shall consider in another connection. We say that acetic acid is a weak acid.

Likewise we may show that ammonium hydroxide is a weak base. In order to demonstrate this I am going to use a substance which belongs to the class of substances known as indicators, that is, substances like litmus which have a different color in acid and alkaline solutions. Here I have a number of such substances which change in color in passing from strongly acid to strongly alkaline solutions, as follows: litmus, red to blue; Congo red, blue to red, phenol phthalein, colorless to purple red; methyl orange, pink to yellow; mauve, yellow to violet; trinitrobenzol, colorless to orange red. The point at which the color change comes is different in the different cases. Thus mauve changes in fairly strong acid solutions, methyl orange in dilute acid solutions, litmus at about the neutral point, phenol phthalein in very dilute alkali, and trinitrobenzol in strongly alkaline solutions. The latter indicator is therefore colorless in all solutions except those in which there is a large concentration of hydroxide ion.

Here I have four vessels containing respectively normal sodium hydroxide, tenth normal sodium hydroxide, normal ammonium hydroxide and tenth normal ammonium hydroxide. I will add to these equal quantities of trinitrobenzol. The first solution is a dark orange, the second a light orange, the third is nearly colorless and the fourth entirely so. If the depth of the color is a measure of the concentration of the hydroxide ion it is apparent that ammonium hydroxide is much less ionized than sodium hydroxide.

In the following lectures, especially when we deal with the subjects of chemical equilibrium and electrochemistry, we shall meet many other phenomena which point almost inevitably to the assumption that salts, bases, and acids are dissociated in solution.

ALGEBRAIC MULTIPLICATION.

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On a recent page of SCHOOL SCIENCE AND MATHEMATICS (p. 296) I find the following:

"Multiplication is the doing to the multiplicand what was done to unity to produce the multiplier * * * it is very vague and readily admits of a vast number of false interpretations * * * For instance, four may be obtained by doubling unity and squaring the result, but multiplying by four is not generally equivalent to doubling the multiplicand and squaring the result."

There has been apparently a complete misunderstanding of the meaning of the rule. The rule says *what was done to unity,* and says nothing about the result. *Squaring the result* (in the illustration above) is not what was done to unity, but what was done to something else than unity. The rule calls for what was done to unity, and for nothing else. What was really done to unity to produce four, was to increase it fourfold. This operation applied to *any multiplicand* will multiply it by four.

Since squaring is a special form of multiplication, if the illustration above had been put into definitional form, multiplication [by 4] is the process of doubling and multiplying, etc., the *circulus in definiendo* would have been apparent at once, and perhaps the criticism would not have been made.

The rule could be emphasized by writing it—doing to the multiplicand what was done to unity in a set of primary commutative operations to produce the multiplier. This would cut out secondary, noncommutative operations, such as squaring the result, extracting square root, etc.; operations which come within the pale of *circulus in definiendo.* These primary commutative operations are those operations which are applicable to other than algebraic magnitudes, reversing, adding, subtracting, doubling, halving, etc. These would excludes the derivation of $\sqrt{2}$ from unity by doubling and extracting the square root. $\sqrt{2}$ is derived from unity by increasing unity in the ratio of 1.414....., a number which, though not writeable in Roman notation or Arabic notation, can be perfectly expressed in strokes (vectors).

To multiply by $-\frac{3}{2}$, since $-\frac{3}{2}$ was produced from unity by reversing, tripling and halving, in any order, we do the same thing to the multiplicand and thus produce the product. This definition holds faultlessly for not only primary number, but also

for fractions, negative numbers, irrational numbers, complex numbers, and quaternion numbers.

The old-fashioned definition of multiplication as a form of addition, taking the multiplicand as many times as there are units, etc., was grossly inadequate and erroneous, failing completely when applied to fractional and negative multipliers, in fact to anything except primary number. The individual who can take a number $\frac{2}{3}$ of a time is not yet born. The true rule is a natural one, forced upon us by the very properties of discrete number. Imagine an investigator with the primary numbers 1, 2, 3..... What can be done with such things? They can be combined accumulatively, which is called addition; or they can be combined decumulatively, which is called subtraction. Or they can have their normality reversed, changed from + to —, called reversion. These operations merely operate on the numbers without changing them, just as piling bricks up leaves them the same bricks as before.

If the investigator is to be allowed to transform the numbers, what shall guide him as to the manner of transformation? What else than the properties of numbers themselves, their size, their differentness from unity? This is the sole property of number, differentness from unity, except the property of sense (+ or —) which is rather an incident than a property. Now if the size of a number, its differentness from unity, is to be our guide for operating, we immediately have a rule for operating upon a number, doing to it what the size of some directing number, the differentness from unity suggests. This is multiplication, the operating upon one number, guided by the properties of some other number called the multiplier. In this we have guided ourselves by the differentness of the number from unity, that differentness which converts unity into the number (multiplier). Had we guided ourselves by the differentness toward unity, the differentness which converts the guiding number (now called divisor) into unity, we get the operation called division, the doing to the operand (dividend) what was done to the operator (divisor) to convert it into unity. Thus, to divide 6 by $-\frac{2}{3}$, we triple, revert, and halve, in any order, since these primary commutative operations will convert $-\frac{2}{3}$ into unity, viz., $6 \div (-\frac{2}{3}) = -6 \times \frac{3}{2} = -9$, the old familiar rule for division by a fraction, invert and proceed as in multiplication.

Most of the current text-books fail dismaliy when it comes to defining division, even those which get the definitiotn of multi-

plication correct. Nearly all of them define division as the inverse of multiplication, a definition correct from one point of view, but grossly inadequate from a pedagogical standpoint. It is much like directing a person up a cliff, reverse the process of jumping down A definition should be positive in its character, not an appendage of something else.

A special case of multiplication, where the *first* operand and every operator is the same, is called involution; $1 \times a \times a \times a = a^3$. A special case of division, where each operator and the *last* operand is the same, is called evolution. The one works *from* unity with always the same operator, the other works toward unity with always the same operator.

Multiplication and division are transformational operations, transforming the operand into a new number; unlike addition and subtraction, which leave the operands unchanged, except as to aggregation and disaggregation. Multiplication and division are strictly algebraic operations, operations peculiar to algebraic number and applicable to nothing else. Addition and subtraction are not solely algebraic, they apply to brickbats as readily as to numbers. Addition and subtraction might be likened to a mechanical mixture, which leaves the constituent elements unchanged; multiplication and division to a chemical mixture which gives an entirely new compound, the constituent elements having disappeared. With these five operations, the investigator can build from primary number, fractional, negative, irrational, transcendental, imaginary, and quaternion numbers, and the rule for multiplication holds right through, the quaternion number evolving from primary number as an inevitable result of adherence rigidly to the definition of algebraic multiplication. To be sure, we find that in the larger field of quaternions, the commutivity of factors is lost, not in spite of the algebraic rule, as so many textbooks teach, but as a consequence of the rule.

In the *Ausdehnungslehre* of Grassman, we have the same operation, multiplication, the operating upon one line, guided by the properties of another line, but the result, naturally, since the properties of lines are entirely different from those of discrete number are entirely different, and upon a superficial view quite discordant. But the discordance is an incident of the things operated upon, and is quite in accord with the general definition of multiplication, the operating upon one magnitude guided by the properties of another magnitude. Here, since the properties of the magnitudes are not differentness from unity, there is no inverse operation, and consequently no "division."

IS THE PRESENT SITUATION IN REGARD TO THE TEACHING OF ALGEBRA IN OUR HIGH SCHOOLS SATISFACTORY?[1]

By H. L. Rietz,

University of Illinois.

Our ideals in education are, as they should be, in advance of our practice; and we can be satisfied with the situation existent at any given time only at the risk of jeopardizing further progress. A negative answer to the question proposed by the committee of this conference is therefore natural but also trivial, and a positive answer is dangerous. The question which is really of importance for discussion at the present time, then, is a narrower one, namely: Are there definite defects in the present teaching of elementary algebra which in the near future and with the means at our command can be, to some extent at least, remedied? As a result of information derived from the experience which the department of mathematics of the University of Illinois has had with its first year classes, and from the inspection of the work of various high schools, I am led to answer this modified question, "Yes."

Observed Facts.

I. *First year students in the university fail in elementary algebra.* For some time past the course in college algebra at this university has been preceded by a brief review of those subjects of elementary algebra most essential as a foundation for the college course. This review lasts two weeks, and is followed by an examination upon the matter covered. The aim has been to ask at this examination only such questions as the student ought surely to be able to answer if he is to pursue successfully the course in college algebra. Credit in college algebra is withheld from the student until this examination has been passed. In this way the department is enabled to judge of the degree in which the entering students are prepared to undertake the work in college algebra, and to form a judgment as to the success of their previous work in elementary algebra. The results of this examination has been somewhat discouraging. In 1906, 190 students, or 40 per cent of the students registered in the course in college algebra failed to pass this examination, and 109 or 23 per cent failed to pass even after a second trial.

[1] From a paper read before the High School Conference held at the University of Illinois, November 22, 1907.

II. *In the high schools algebraic manipulation is mechanical, and directed by rule rather than reason.*

In subjects of an engineering course which require algebra, we hear the complaint that students make the most serious blunders in simple algebraic manipulation. This is, in part, due to misdirected work in elementary algebra. To illustrate, let me give one or two recent observations: the problem to simplify $\frac{1}{\sqrt{1}}$ was under discussion. It was taken from the text, and following the model problem, the student obtained $\frac{\sqrt{5}}{5}$, but the important question as to the purposes for which $\frac{\sqrt{5}}{5}$ is simpler than $\frac{1}{\sqrt{5}}$ were not mentioned.

Again, required, to rationalize the denominator of $\frac{1}{\sqrt{3}-\sqrt{2}}$ When such problems are given to a pupil with nothing but a model problem as a guide, why should he not regard this part of algebra as sort of evil visitation with which to punish high school students? Further, observation shows that there is much manipulation with equations, and that answers are obtained to problems in the text, but the importance of verifying and interpreting results does not seem to be realized.

Reasons and Remedies.

Since the foregoing conditions obtain, the following questions seem to arise naturally: Is the defect in the teaching, or in the subject matter, or in both?

I. *Algebra is popularly regarded as easy to teach.* Algebra has, I think, been regarded as a subject singularly easy to teach. It has been looked upon as a proper subject for evening up the program of the corps of instruction, or as a subject to be taught by some one who can teach nothing else. If any mathematical subject must be used to even up teaching programs, I wish to raise the question whether it would not be safer to use a more concrete subject such as geometry. Much has been written within the past few years about improvements in the teaching of secondary mathematics, and some successful experiments have been made which have done something to improve conditions; but it appears to me from visiting high schools that the influence of recent movements has not yet been so far reaching as might be wished.

II. *The pedagogy of beginning algebra is imperfectly understood.* The problem as to what is pedagogically fundamental in making the transition from arithmetic to algebra is not, I think, thoroughly understood, nor are its details well worked out by all

teachers of elementary algebra. I believe the discussions on this point in SCHOOL SCIENCE AND MATHEMATICS would be found helpful to any teacher. All are agreed, I think, that many logically fundamental theorems cannot be presented in high school algebra, and that it is best to make broad assumptions which are sufficient, and are readily admitted by the student from his previous experience, but which are not necessary, in all cases, for the logical development of the subject.

What, then, are the particular points which the instructor should have in view in teaching elementary algebra? In other words, what is the educational purpose of this subject? We could well say broadly that it is to take care of the quantitative side of the life of the child, but this ideal is not restricted enough to form a working basis for teaching. We may, I think, well direct our attention more specifically to the following points which seem to justify the study of algebra:

a. The solution of problems which are closely related to the experience and daily life of the student, and which are not easily solved by arithmetic.

b. The review and extension of arithmetic by making algebraic principles grow out of the arithmetic relations. This includes a body of knowledge valuable for its own sake.

c. Preparation for college mathematics.

The use of algebra to solve problems which seem worth while but are too difficult for unaided arithmetical analysis presupposes on the part of the teacher a knowledge of the relation of algebra to various other subjects. This demands broad experience with quantitative things and careful selection of problems from this experience. The use of arithmetic as an introduction to algebra presupposes that the teacher has worked out so clear a presentation of the gradual extension of the number concept that the pupil comes to appreciate the significance of the various classes of numbers dealt with in algebra. These extensions should, first of all, be made to appear important. There are, in general, three points which may be emphasized in this connection: first, that the description of certain concrete experiences is facilitated by the use of these additional numbers; second, that this extension is demanded in order that the fundamental operations may be applied to the numbers of arithmetic without exception; and third, that the equation itself demands the extension. In this connection, and from the start, the student cannot be taught too emphatically to regard the equation as the chief object of algebraic inquiry.

With reference to preparation for college mathematics, I do not have in mind that the teacher should exert himself particularly to prepare the pupil to pass entrance examinations, but rather that he should present the point of view that the subject is one capable of further development, that the student should, to a considerable extent, be kept in the attitude of a discoverer of new truth. The proper direction of the student who looks forward to college work, and probably that of any other student, presupposes, in general, that the teacher has had at least two years of college mathematics. Without this, I fear it is exceptional if his view and outlook are such that he can discriminate between essentials and nonessentials for further mathematical progress.

III. *Correlation.* Those interested in the improvement of secondary mathematical instruction have written much in recent years concerning the closer correlation of algebra, geometry and more concrete sciences. The thought has been to make mathematics more generally useful by developing it in union with the branches to which it is related, and by unifying the branches of elementary mathematics so that each may take a more important place in developing the others. It is argued that mathematics thus becomes a more usual and important instrument for describing the phenomenal world, and that, in turn, pure mathematics is much enriched by such a broadening of its applications. A few interesting experiments have been made, and any teacher of mathematics would profit by reading the reports of these experiments.*

It seems to me that in the hands of a skillful teacher, a close correlation should help to attain the purposes of algebra as outlined above. At least there is no doubt that efforts at correlation will improve conditions by rendering algebra concrete, by visualizing it, and by broadening its application so as to touch the daily life of the student, even if no decided reorganization of the subject matter is effected.

IV. *Position of algebra in high school course.* In a large per cent of our high schools, algebra is taught during the first three half-years of the high school course, and I am told that the student has then nothing further to do with algebra except as it may be needed in geometry taught from a standard text. I have some data as to the number of high schools with this arrangement for algebra. Of the students who have taken freshman mathematics at the University of Illinois in the past four years, 57 per cent

*School Review, Oct., 1907.

came from high schools in which algebra is completed in the second year of the course. It seems to me this ought not to be so. In some schools, algebra is taught for one year, followed by geometry for a year and a half, and then the work in high school mathematics is completed by a course in algebra in the latter part of the third or in the fourth year. This arrangement will surely tell on the results. I have some statistics on this point: Of the students who failed to pass the elementary algebra review examination, 64 per cent had no algebra after the second year of high school, 17 per cent completed algebra in the third year, and 8 per cent completed it in the last year. The remaining 11 per cent entered in ways which made it impossible to classify them. It appears from this that, in a large proportion of the high schools which furnish these unqualified students, algebra is completed in the second year. In fact 64 per cent of the failures were furnished by high schools in which algebra is completed in the second year while only 57 per cent of our students came from such schools. Further, let us consider the total enrollment in college algebra in the University in the first semester of 1906: In the review examination, of those who completed algebra in

1903 or earlier ....48% failed
1904.....38% sailed
1905.....35% failed
1906.....32% failed

This again shows that the time element is of significance, and leads to the question whether the situation as regards the teaching of algebra can not be immediately improved by giving one year of algebra, followed by one and one-half years of geometry and by ending the secondary mathematics with one-half year of algebra, even if we are not ready to adopt more radical changes? The geometry would open a great field for the visualization of the second course in algebra, and help to make the algebra more important. I have suggested this arrangement where the other arrangement exists, and the only objection offered is that many text books are not well adapted to it. I do not think this an important objection; for, some text-books were written with the better arrangement in view.

V. *Slavery to text-books.* Since the question of slavery to text-books has arisen, it may be worth while to consider the tendency and bearing of the text-book on the efficiency of teaching. Max Simon, prominent in Germany in the pedagogy of

mathematics, says, in a recent article, that the student cannot be turned away strongly enough from the text. For boys between eleven and twelve years old, he holds the use of a text-book to be a sort of crime. The logarithmic table is the only book he considers absolutely necessary. The instructor will, so far as it is at all possible, present the theorems in their natural order of development, so that the student feels that he has discovered them himself. The text-book, on the contrary, is dogmatic. The student is to give his assent and remember.

While this may be an extreme view, yet if the use of a text-book means that a well prepared teacher follows it strictly, feeling it his chief duty to teach the book rather than the subject, then it is better to have no text at all. How much more life there is in the problems which the teacher prepares than in those in our very best text-books! Do not understand that I am advocating lecture courses for high school students. Such intellectual dress parades are entirely out of place in a high school, but what we lack is sufficient free and independent discussion, and much work outside of the text given out by the living voice of the teacher. The teacher must come to use the text merely as a means to definite ends, and as such it can serve useful purposes; but when a text is used to make the work of the teacher easy, it has few virtues and many faults.

VI. *Purpose of manipulations should be emphasized.* Reference has already been made and illustrations cited in the matter of algebraic manipulations. What is the remedy? To revert to the illustrations of simplifying $\frac{1}{\sqrt{5}}$ and $\frac{1}{\sqrt{3}-\sqrt{2}}$, why not precede such tasks by asking the pupil for an approximate idea of the length of a string when given by $\frac{1}{\sqrt{5}}$ inches or $\frac{1}{\sqrt{3}-\sqrt{2}}$ feet, or ask him to express $\frac{1}{\sqrt{5}}$ or $\frac{1}{\sqrt{3}-\sqrt{2}}$ correct to three decimal places, and see whether his own judgment will not lead him to rationalize the denominator. If he does it awkwardly it will be a valuable lesson in finding what the better method is. In fact, there are many ways, by close contact with concrete things and with the daily life of the student, by which the student can be made to understand the purposes of algebraic manipulations. One of the most fruitful fields for practice in manipulation is found in the verification of the results of solving equations, and deriving formulas. This has the further advantage of being an operation fundamentally important in itself but entirely too much neglected. For the student soon comes to problems where extraneous solutions are introduced, and such substitution in the

original equation lends importance to the equation as a condition to be satisfied.

To summarize, it appears that there is good ground for dissatisfaction with the present situation in regard to the teaching of algebra in our high schools. The defect is both in teaching and in subject matter. The problem as to what is pedagogically fundamental in making the transition from arithmetic to algebra must be worked out in detail by every teacher, and this requires careful and painstaking effort. This problem must be solved by a consideration of the aims, ends, and limitations of a course in elementary algebra.

Improvements are suggested by a closer correlation of algebra with other branches of study, and with the experience of the pupil, thus rendering aglebra concrete and real in the sense in which a high school student sees reality. This correlation may ultimately mean the unification of different mathematical subjects into one course. To effect an immediate advance we have raised the question of giving one-half year of algebra after the student has had geometry. As an improvement in our teaching, should we not constantly have less of slavery to text books, and more independent thinking on the part of teacher and student, so as to lead the student into the attitude of a discoverer? The cultivation of this attitude and habit of thought is, after all, of the most vital importance. An American school boy transplanted to a German gymnasium at the age of fifteen said once in answer to a question concerning German and American schools: "In America we recited lessons, here we are taught something." May we not make the class room less a place for the recitation of a mass of half digested facts and processes and more a place for the natural building up of the subject by the well guided development of the pupil's own ideas?

INDEFINITE DEFINITIONS.

By G. W. Greenwood,

Dunbar, Pa.

Among the definitions of the twelfth book of Euclid we find the following:

Equal and similar solid figures are those that are contained under equal numbers of similar and equal planes.

Nothing is stated concerning the arrangement of the faces, but it is easy to show that if this be not included then two solids whose faces are respectively congruent are not themselves neces-

sarily congruent; for example, two symmetric solids are not in general congruent. Again, consider two pyramids whose bases are congruent equilateral triangles, but which are not in any other sense regular; we can apply the one to the other in three different ways so that their bases are coincident, thus forming three entirely different polyhedrons whose faces are respectively congruent.

But can we form two different solids whose faces are respectively congruent and arranged in the same order? This question was taken up by the learned Dr. Robert Simson, of Glasgow, in his edition of Euclid (1834), where he very properly asserts that this is no definition, but a theorem which should be proven, not assumed. In fact, he supposes that this was given as a theorem by Euclid, but that Theon, or some other editor, ignorantly changed his demonstration into a definition; he seems to hold Theon responsible for all lack of rigor which he finds in the text as it has come down to us. Thereupon he proceeds to show that the theorem is not true, prefacing his demonstration with these interesting remarks:

"But if this proposition be not true, must it not be confessed, that geometers have, for these thirteen hundred years, been mistaken in this elementary matter? And this should teach us modesty, and to acknowledge how little, through the weakness of our minds, we are able to prevent mistakes. . . ."

He then proceeds somewhat as follows:

Within a triangular pyramid V-ABC take a point D. Draw DA, DB, DC. Take the point E symmetrical to D with respect to the base. Then the solids V-ABC-D and V-ABC-E have the same faces and arranged in the same order, but they are evidently not themselves congruent. It will be noticed, however, that the trihedral angle at D is re-entrant, and the question arises as to whether or not we can have two *convex* solids whose faces are respectively congruent and arranged in the same order. Legendre, in his geometry, shows that such solids *are* congruent, the theorem having been proven by Cauchy, who, we are told by Todhunter, turned his attention to this question at the request of Legendre. Hence, if we include the restriction that the polyhedrons be convex and the faces arranged in the same order, the statement is true, though it is no more a definition than is the statement that congruent triangles are those whose sides are respectively congruent.

Inasmuch as the theorem is difficult to prove, and also un-

necessary in elementary geometry, it is now properly omitted from text books.

It is interesting to note, however, that in the same group of definitions we find the following:

"A Prism is a solid figure contained under Planes, whereof the two opposite are equal, similar, and parallel, and the others Parallelograms."

Had Dr. Simson noticed that this definition is wholly inadequate, he would probably have accused Theon, or some other editor, of substituting it for some rigid definition which Euclid had given. Though this definition is even now given in many current texts, and duly memorized by students, it is no more a definition of a prism than would the statement that "a circle is a closed curve" define a circle. It would seem, therefore, that geometers have been mistaken for these fourteen hundred years concerning another elementary matter; "and this should teach us modesty."

On opposite sides of a polygon as a base construct genuine prisms, the conterminous edges not being collinear, and we thus obtain a figure having two faces parallel and congruent, whose remaining faces are parallelograms, but which is not a prism. However, the solid thus formed is not convex. To construct a *convex* solid satisfying this definition, but which is not a prism, we may proceed as follows:

Take a regular quadrangular prism; call the bases ABCD and A′B′C′D′, respectively, A and A′ being the end points of the same lateral edge, etc. The mid points of AA′, BB′, CC′, DD′, call A″, B″, C″, D″, respectively. With the planes AB″C, BC″D, CD″A, DA″B, cut of one end of the prism, which end will then be closed by four congruent parallelograms having as a common vertex the center of the original square, ABCD. Now cut off the other end of the prism by the planes A′B″C′, etc., and the resultant polyhedron will have six pairs of faces, each pair comprising two opposite, parallel, and congruent faces; and since all the faces are parallelograms, it follows that the solid so formed satisfies the Euclidean definition of a prism. It is believed by the writer we can always construct a solid having $2n(2n-1)$ sides, n being any integer greater than unity, satisfying and refuting this Euclidean definition, all faces being parallelograms congruent and parallel in pairs. The above solid, as well as many serving the same purpose may be easily cut out of a cake of soap.

Of course every geometry, including many current texts, which uses this definition, is wholly fallacious in all that pertains to prisms, and therefore to pyramids, cones, cylinders and spheres.

ILLUSTRATIONS AND APPLICATIONS IN THE TEACHING OF PHYSICS.*

By Willard R. Pyle,
Morris High School, New York City.

Of what value are illustrations and applications; and why do they not figure more prominently in our teaching? I shall try to touch upon the question from several points of view, and if I succeed in saying anything to stimulate thought or to provoke discussion, I shall feel satisfied.

It is a growing conviction with me that the most effective, interesting and profitable way of getting a high school boy or girl to comprehend the significance of a physical law or principle is by studying the illustrations and applications of it in things more or less familiar.

Our pupils come to us with a surprisingly vague understanding of natural laws even though qualitatively expressed. What few definite notions they have about physical phenomena are often most erroneous. They all think that smoke settles on a humid day because the atmosphere is heavy, that the chimney draws air from the kitchen into the stove to make the draft, that an engine does work, that bodies in motion come to rest of themselves, that a horse pulls harder upon the wagon in drawing it than the wagon pulls upon the horse, that a body floats because it is lighter than the liquid or gas it floats in, that dew falls, that steam is visible, that ice is never colder than the freezing point, that water boils because the heat continually drives air out of it, that a perpetual motion machine is a most reasonable thing, that ice keeps a refrigerator cold because the ice itself is cold, the melting of it being a most unfortunate thing, that opening a door in winter lets in the cold, etc., etc. There seems no limit to it when we study these third-year boys and girls well enough to appreciate their actual state of knowledge. They are without exaggeration almost as ignorant of the true nature of common physical phenomena as the Irish servant who in the morning opened the shutters to let out the dark. Do we not often expect too much of our pupils, forgetting how immature they are, and how uninformed about nature's way of working? Do we keenly realize that for the sake of the pupils, improvement may yet be made in the treatment of the subject?

*Read before the New York Physics Club, New York City.

I do not have a great amount of fault to find with our present syllabuses. They seem for the most part to read about right. The trouble is that we in our teaching are misplacing the emphasis. It should be laid more largely upon the illustrations and applications, and less upon pure science, exact relations, and physical constants. It is generally admitted that the best trained minds in this country today are the men who have been graduated from our engineering schools and schools of applied science; they are no longer the classical men. Are we not then doing the best and most helpful work when we teach useful things that young people naturally study with enthusiasm? We must learn to teach qualitative physics and the practical applications in such a way that pupils will still be compelled to work and think. A teacher enthusiastic chiefly about pure science rather than the pupil, and filled with a preconceived notion of what is best to teach usually fails largely to understand his pupils, and mistakes his own enthusiasm for that of the children.

It is well known that university professors as a rule feel little interest in the needs of the average high school boy or girl. Many of them declare explicitly that they care nothing at all about the greatest good to the greatest number. They think and care only for the few in the high school who are going to college. Now, in all reason, should people who assume that attitude towards public education have much if any influence in settling how a subject shall be taught in the public schools? We are influenced too much by the colleges, and we are doing too little to make physics of practical value to the great majority who will never go to college. Since we naturally want the small per cent of pupils who are going to college to pass the entrance examinations for their good and our glory, some of us teach strenuously to all certain topics that we would gladly pass lightly over as unworthy of emphasis, thus making it impossible for lack of time to teach many things the children ought to know. It is a disgrace, for instance, the way we slight electricity. Considering the age in which we live, it deserves twice the time at least. Year after year pupils come to us eagerly looking forward to the electrical applications only to quit physics sorely disappointed. Physics as taught today is a fine example of a subject taking precedence over the claims of pupils. I heard dean Balliet a few years ago express his opinion of the Harvard course in physics. He said in substance that the Harvard course in physics is the worst thing ever perpetrated in secondary science teaching.

In January Columbia University gave an entrance examination in physics that consisted of 13 questions, 11 being problems. Ten of these 13 questions had to be answered. It would seem from this that some people think the object of a year's work in physics is to acquire the ability to solve problems, and that the physics department is largely a department of applied mathematics. It is most unfortunate because it encourages and maintains misplaced emphasis in high school teaching and crowds out to a large extent qualitative physics and a proper consideration of the applications. It ought to be possible, and I claim it is possible, for the colleges to test for both knowledge and power in science in other ways than by arithmetic.

What is the object of problem solving? Perhaps it is to give mental discipline. The article by Wardlaw in the January Educational Review makes us wonder, however, whether there is after all any such thing as mental discipline. Perhaps it is to make a pupil's knowledge of principles more real and accurate, so that he may have, as it were, a "working knowledge" of the subject. This appears more rational, and seems a sufficient justification of problem work. But are we not relying too exclusively upon the problem to furnish that clear understanding, that "working knowledge," which makes physics useful to an individual later in life? I think we are. There should be more study of laws and principles as they appear in operation in the world of nature about us, and in the many devices and inventions in our homes and about the city. To my mind the clearest understanding that anyone, old or young, can ever get of a natural law is by studying that law in operation.

Let me give you an old familiar stock problem: "How great was the free mass acted upon, if a force of 3 dynes in 2 seconds changed its velocity 10 centimeters per second?" What do you suppose a pupil is thinking about when he solves that problem? Is he thinking of a metal disk revolving on ball bearings, a pendulum bob swinging on a long suspension, two unequal masses suspended over a so-called "frictionless" fixed pulley, a mass sliding on a very slippery inclined plane? What is he thinking about? Nine times out of ten he is just like his teacher! He has no adequate, or approximately adequate, accompanying physical concept at all. He is simply juggling with figures and getting answers. Why that is not difficult mathematics, it may be argued in defense. True; it is very easy mathematics. It is also husks of

science when offered to high school girls and boys; lifeless, unprofitable, deadening physics. We have no time to waste on such abstractions. I have quit teaching it, college professors and syllabus interpreters to the contrary notwithstanding.

Why do pupils who can readily solve problems in f=ma and ft=mv find it impossible to tell why an elevator cable pulls more than the weight of the car and occupants while gaining velocity going up, and less than the weight of the car and occupants while gaining velocity going down; or, as on the last regents examination, why a falling body on striking the earth exerts a pressure in excess of that due to its weight? It is because they have no real, vital, permanent understanding after all of the relation of force, mass, and acceleration. They were taught according to the usual interpretation of the syllabus, and in a way to delight the college professor, but with the result that they largely missed the idea, they did not see the woods for the trees, the mathematics eclipsed the physics; in a nut shell, *the quantitative excluded the qualitative*. One may argue very plausibly that the quantitative includes the qualitative, and it would seem as if it must be so; but in practice we find that not infrequently the quantitative actually excludes the qualitative, the example just given being a case in point. Nearly 14 years of continuous class-room service as a physics teacher have made it very evident to me that to include the qualitative we must actually teach the qualitative as such by illustrations and applications.

Let me try in another way to make my attitude clear. I maintain that it is more valuable from the standpoint of intelligent citizenship for the average boy and girl in our high schools to understand refraction of light in a qualitative way, and be able to explain the rainbow, its circular shape, and the order of its colors, the illuminating of dark basements by pavements composed of glass prisms, the use of lenses for near sight and old sight, the accommodation of the lens of the eye, and the common optical instruments than it is to be able to do such things as define index of refraction, describe a method of determining it, and tell where errors are most likely to creep in.

It is more important, for instance, that we teach expansion and contraction of gases in a qualitative way, and the applications of it in convection (drafts, methods of ventilating a room, seabreeze trade-winds, etc., together with a thorough study of the why and wherefore of the principle features of some direct or in-

direct method of heating a home or school building) than it is to determine the coefficient of cubical expansion of gas and then solve problems involving the absolute zero. I do not advocate technical or engineering physics, but rather a study of those common applications that illustrate best the principles we are attempting to teach. What could be more interesting and valuable than a careful study of the whole process of manufacturing the rectangular slabs of ice that we all see everywhere about us in the city? Think of the many energy transfers, and the inclusiveness of such a study. We deliberately slight that, however, while capillary tubes and floating needles are made prominent.

Nothing should be retained in the physics course solely on the ground of mental discipline. If a topic is of no practical use or of small practical use, and at the same time does not furnish information that an intelligent citizen should possess, let us cut it entirely out of our teaching.

As a general sees a situation more clearly than the privates fighting in the ranks, so school administrators and students of educational problems often understand a situation better than a body of subject teachers. Let me then in closing quote briefly from a recent address by Dean Balliet. "To the immature mind interest in natural science * * * lies not in the pure science, but in the applications of the science to the phenomena of nature and to our industrial and social life. The establishment of laboratories in our secondary schools, while it was a great step in advance, has not developed, after all, an interest in science to the extent it was hoped it would. * * * Now, the natural sciences are intrinsically interesting to pupils of the secondary school age if well taught, and when they are not, the teaching is at fault. In our laboratories the pupil makes his experiment, observes the result, formulates a generalization and writes it in a note-book. That in most cases is the end of it. He does not know what his generalizations mean beyond the fact that they seem to explain the phenomena observed in the experiment, and these phenomena are neither intrinsically interesting nor exceptionally important to him. If, on the other hand, the teacher would take these laws and principles formulated in the laboratory out of doors and lead the pupil to use them as a key to unlock the mysteries of physical nature and of life, they would acquire a meaning for the pupil and an interest which they can not possibly have as mere generalizations. *There is more educational value, to an*

immature mind at least, in knowing one principle in physics and seeing fifty applications of it in the interpretation of the phenomena of nature or the facts of life than in knowing fifty principles as mere generalizations of the laboratory. There is no reason, for example, why in physics the whole of meteorology in its elements should not be taught, for it is little else than applied physics. * * * In short, the sciences should be taught as applied science to beginners in secondary schools * * *; in college and the university they may be taught in their more abstract form as pure sciences."

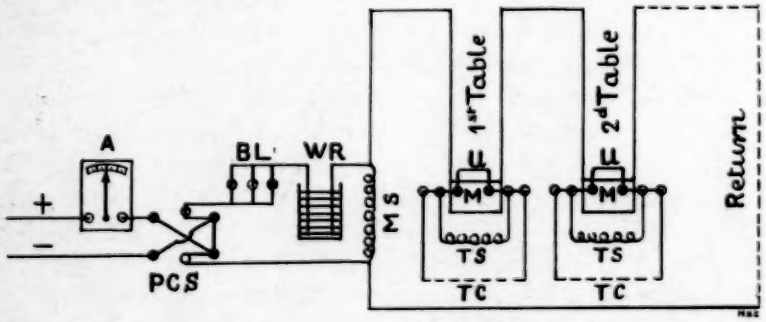
THE USE OF 110 VOLT DIRECT CURRENT IN THE LABORATORY.

By W. M. Butler,

McKinley High School, St. Louis, Mo.

It is hoped that the description and sketch here given may be helpful to teachers, whose time and patience have been sorely tried by the failure of the common battery at the moment when it was needed.

If direct current is not available, then one of the electrolytic rectifiers now commercially on the market will serve as the source of current, and all arrangements after rectification of current may proceed as below stated.



For this purpose it will be found most convenient to connect all of the tables in series, as this is easiest wired up and makes possible the use of a good ammeter for precise determination of the currents in use.

The figure requires the following explanation:—

A is the ammeter, best one with zero at center of scale. P C S is a double throw, double pole switch, wired as shown for re-

versing the current at the student's table, though the main current is not affected by its use. It will not do, to replace this switch by a common pole changer, as that will in use become a "short on the line," for reasons understood by any one on examination of its parts.

B L is a bank of lamps containing a number suited to give a rough adjustment of the strength of current that may be desired for use.

W R is a water rheostat, adapted to regulate the current more exactly than the lamps can do. Water with a drop or two of sulphuric acid and platinum electrodes serves very well. By changing depth of immersion and distance apart, current may be exactly regulated to the desired strength.

M is a block of wood at the student's table, containing two mercury cups, to which the lead binding posts carry current.

M S is the main shunt for regulating the voltage to be used on the student's table circuits.

T S is the table shunt, which regulates the current taken by the Table Circuit, T C . This may be made of No. 26 german silver wire, and its length may be made such as to give a suitable voltage, 30cm. being enough for slide wire bridge work, when the main current is .5 ampere.

It will be noted that if the copper U is lifted out of the mercury cups, the table circuit will come into use; with the U in its place, no current can reach the instruments of the student.

In practice, the current is roughly regulated by turning on lamps; and is then precisely adjusted by the water rheostat; after this is done, the student goes to work, being reasonably sure of a steady current, since his instruments at the table have so small a resistance compared with that of the bank of lamps that the main current is not affected by what is done at the individual table.

If a large current is desired, then the shunts are removed, and the current adjusted as before. Then on removing the U at each table, the current to be used passes through the instruments of the table corresponding.

This arrangement is suited for any work for which current is desired, ranging from .01 to 10A, and is perfectly flexible within so extreme a range.

The parts A, B L, W R, M S and P C S should be on the instructor's table.

PROBLEM DEPARTMENT.

IRA M. DELONG,

University of Colorado, Boulder, Colo.

Readers of the Magazine are invited to send solutions of the problems in this department and also to propose problems in which they are interested. Problems and solutions will be duly credited to their authors. Address all communications to Ira M. DeLong, Boulder, Colo.

Algebra.

99. Proposed by S. Epsteen, Boulder, Colo.

Express as a determinant of the $n+1$st order, $(x-a_1)(x-a_2)\ldots\ldots(x-a_n)$

Solution by I. L. Winckler, Cleveland, Ohio.

The determinant is:

$$\begin{vmatrix} x & b_1 & b_2 & b_3 \ldots b_{n-1} & 1 \\ a_1 & x & c_1 & c_2 \ldots c_{n-2} & 1 \\ a_1 & a_2 & x & d_1 \ldots d_{n-3} & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ a_1 & a_2 & a_3 & a_4 \ldots x & 1 \\ a_1 & a_2 & a_3 & a_4 \ldots a_n & 1 \end{vmatrix}$$

where $b_1, b_2 \ldots b_{n-1}$; $c_1, c_2 \ldots c_{n-2}$, etc., are any quantities. If we multiply the last column by a_1 and subtract from the first $x - a_1$ is seen to be a factor. Similarly $x - a_2 \ldots x - a_n$ are found to be factors.

Remark by the Proposer.

Aside from a constant factor (the reciprocal of the first minor of x^n) we may write:

$$\begin{vmatrix} x^n & a_1^n & a_2^n & \ldots . a_n^n \\ x^{n-1} & a_1^{n-1} & a_2^{n-1} & \ldots . a_n^{n-1} \\ . & . & . & . \\ x & a_1 & a_2 & \ldots a_n \\ 1 & 1 & 1 & \ldots . 1 \end{vmatrix}$$

103. *Proposed by J. J. Browne, Colorado School of Mines, Golden, Colo.*

Factor: $(la' + l'a)^3 (bc' - b'c)^3 + (lb' + l'b)^3 (ca' - c'a)^3 + (lc' + l'c)^3 (ab' - a'b)^3$.

Solution by the proposer.

Since $x^3 + y^3 + z^3 = 3xyz$ when $x + y + z = 0$, it follows that the desired factors are

$3(la' + l'a)(lb' + l'b)(lc' + l'c)(bc' - b'c)(ca' - c'a)(ab' - a'b)$.

104. *Proposed by I. L. Winckler, Cleveland, Ohio.*

A company of n men were counting their money. The first said to the second, "Give me your money and I will have a dollars." The second said to the third, "Give me one-half of your money and I will have a dollars." The third said to the fourth, "Give me one-third of your money and I will have a dollars."..... The nth said to the first, "Give me one-nth of your money and I will have a dollars." What sum had each?

Solution by Walter L. Brown, Fancher, N. Y.

Let x_r be the rth man's money, then

$x_{r-1} + x_r/(r-1) = a$, whence

$x_r = (r-1)(a - x_{r-1}) = (r-1)a - (r-1)x_{r-1} = (r-1)a - (r-1)(r-2)a + (r-1)(r-2)x_{r-2} = (r-1)a - (r-1)(r-2)a + (r-1)(r-2)(r-3)a - (r-1)(r-2)(r-3)x_{r-3} = \ldots\ldots$

$x_n = [(n-1) - (n-1)(n-2)\ldots + (-1)^n(n-1)!]\,a + (-1)^{n+1}(n-1)!x_1$ ..... (1)

But $x_n + 1/n\,x_1 = a$, $\quad x_1 = na - nx_n$ ..... (2)

From equations (1) and (2), $x_n =$

$$a\left\{\frac{(n-1) - (n-1)(n-2) + \ldots (-1)^n(n-1)! + (-1)^{n+1}n!}{1 + (-1)^{n+1}n!}\right\}$$

$$x_1 = a\left\{\frac{n(n-1) - n(n-1)(n-2)\ldots + (-1)^n n! - n}{(-1)^n n! - 1}\right\}$$

From the formula, x_r is known in terms of x_{r-1}, so that x_2 is known from x_1, x_3 from x_2 etc.

Geometry.

105. *Proposed by Chas. Jenney, Hingham, Mass.*

Let the sides of a triangle ABC be divided into m equal parts. Call the nth point of division from A on AB, F, the nth point from B on BC, D, and the nth point from C on CA, E. Draw DE, EF, and FD.

Now divide each side of DEF into m equal parts. Call the nth point from D on DF, G, the nth point from F on FE, H, and the nth point from E on ED, K, and draw GH, HK, and GK. Then the sides of GHK are parallel respectively to the sides of ABC.

I. Solution by G. B. M. Zerr, Ph.D., Philadelphia, Pa.

Let ABC, DEF, GHK be the triangles as stated in the problem, I the nth point of division from C on CB; then EI is parallel to AB. $BI = DC = (m-n)BC/m$, $BD = nBC/m$, hence $BI = (m-n)BD/n$. Let EI cut FD in L, then $FL = (m-n)FD/n$; $FG = (m-n)FD/m$, hence $GL = FL - FG = (m-n)^2FD/mn = (m-n)FL/m$.

But $HE = (m-n)EF/m$; therefore GH is parallel to EI and also to AS. In a similar manner GK is proved parallel to BC and HK to AC.

II. Solution by A. W. Rich, Worcester, Mass.

From points G and H draw parallel to AB the line GX, meeting BC in X and the line HY meeting AC in Y.

$BD/BC = m/n$, $BX/BD = (m-n)/m$; $BX/BC = n(m-n)/m^2$

$AE/AC = (m-n)/m$, $AY/AE = n/m$; $AY/AC = n(m-n)/m^2$

$\therefore$ $BX/BC = AY/AC$, and a straight line from X to Y would be parallel to AB; this line would contain the points G and H and therefore line GH is parallel to AX. In the same way GK is shown to be parallel to BC and HK to AC.

III. Solution by T. M. Blakslee, Ph.D., Ames, Iowa.

If the vectors from A to B, C, ... are denoted by these letters,

$$E = \frac{m}{n}C,\ F = \frac{m-n}{m}B,\ D = \frac{(m-n)C + nB}{m},$$

$$K = \frac{n^2C + (m-n)^2C + n(m-n)}{m^2}B,\ H = \frac{n(m-n)B + (m-n)nC}{m^2}.$$

Hence KH or HK is a multiple of C or AC and HK is parallel to AC.

CREDIT FOR SOLUTIONS RECEIVED.

Algebra 82. J. W. Ellison. (1)
Algebra 98. M. L. Constable, Pauline M. Davis. (2)
Algebra 99. Walter L. Brown, W. L. Malone, I. L. Winckler, G. B. M. Zerr. (4)
Algebra 103. J. J. Browne, Walter L. Brown, W. L. Malone, A. W. Rich, I. L. Winckler, G. B. M. Zerr. (6)
Algebra 104. T. M. Blakslee, Walter L. Brown, W. L. Malone, A. W. Rich, I. L. Winckler, G. B. M. Zerr. (6)
Geometry 101. Pauline M. Davis. (1)
Geometry 105. T. M. Blakslee (2 solutions), Walter L. Brown, W. L. Malone, A. W. Rich, I. L. Winckler, G. B. M. Zerr. (7)
Total number of solutions, 27.

PROBLEMS FOR SOLUTION.

Algebra.

Proposed by Calvin M. Woodward, Dean of School of Engineering and Architecture, Washington University, St. Louis, Mo.

A merchant gave four workmen a pile of oranges to be divided at the close of the day. A finished first and went alone to get his share. He counted the pile and found that if he gave one to a monkey chained hard by, the remainder would be divisible by four. So he gave one to the monkey, took his fourth and went home. Next B came, and thinking himself the first, he too counted the pile, gave one to Jocko, took his fourth and went home. Later C, and at last D, came and each did exactly the same thing. Next morning the men met and on comparing notes, agreed that there must be a pile left. So they went together to the orange room and counted the pile. They then found, as each had found before, that if one were given to the monkey, as hungry as ever, that the remainder would be exactly divisible by four. So the monkey got his fifth orange and the last pile was divided. How many oranges were in the original pile?

(If desired, the problem may be made general by having n men, and after each counting giving the monkey a oranges.)

Geometry.

Proposed by C. S. Cory, Cedar Falls, Iowa.

Draw a circle that shall pass through a given point and touch two given unequal circles.

Proposed by William B. Borgers, Grand Rapids, Michigan.

In several geometries (for example, in Wells' Solid Geometry, page 251, Ex. 5) the question is asked, "What is the locus of points in space equally distant from a given plane?" Discuss the question: Is this a definite problem?

Trigonometry.

Proposed by Mrs. Harold Blair, Mt. Clemens, Michigan.

Show that $\sin(\lambda''-\lambda') - \sin(\lambda'' - \lambda) + \sin(\lambda' - \lambda)$ may be reduced to $4\sin\frac{1}{2}(\lambda' - \lambda)\sin\frac{1}{2}(\lambda'' - \lambda')\sin\frac{1}{2}(\lambda'' - \lambda)$. (From Crockett's Trigonometry.)

Applied Mathematics.

A squirt gun has a hole $^3/_{32}$ of an inch in diameter. It is held vertically upwards and a pressure of 50 pounds is applied to the piston which is $\frac{7}{8}$ of an inch in diameter. Neglecting all resistance, (a) how high will the water rise? (b) if held horizontally 10 feet from the ground what will be its range?

GREATEST LUMBER CUT.

More lumber was cut in the United States last year than in any other year in its history. The enormous amount of 37,550,736 board feet was produced, and the mill value of this was $621,151,388. In addition, there were produced 11,858,260,000 shingles, valued at $24,155,555, and 3,812,807,000 lath, valued at $11,490,570. On the whole, it is safe to say that the present annual lumber cut of the United States approximates 40 billion feet, and that the total mill value of the lumber, lath, and shingles each year produced is not less than $700,000,000. These figures give some idea of how vast is the lumber industry and how great is the demand for its products.

A glance at the kinds of lumber produced shows very clearly the passing of white pine and oak, one the greatest softwood and the other the greatest hardwood which the forest has ever grown. Since 1899 the cut of white pine has fallen off more than 40 per cent, while that of white oak has fallen off more than 36 per cent. To-day and this will be a surprise to many—comes second. Since 1899 the cut of Douglas fir has increased 186 per cent. Louisiana is the foremost yellow pine State, with Texas, Mississippi, and Arkansas following in order. Washington produces by far the greatest amount of Douglas fir.

A comparison of the lumber-producing States shows that since 1899 there have been many changes in their relative rank. Washington, which in 1899 stood sixth, now leads, while Wisconsin, which eight years ago led all others, is now third. In the same period Oregon, Louisiana, Mississippi, Idaho, and California made great strides as lumber-producing States, though, on the other hand, the amount produced in Michigan, Wisconsin, Minnesota, Georgia, Kentucky, Tennessee, Missouri, Indiana, and Ohio fell off anywhere from 29 to 54 per cent.

The highest-priced native woods are walnut, hickory, and ash, and the cheapest are larch and white fir. From the fact, however, that since 1899 the average increase in the price of lumber has been 49 per cent, it will not be long before cheap woods are few and far between.—*Forest Service.*

SCIENCE QUESTIONS.

By Franklin T. Jones,

University School, Cleveland, Ohio.

Propose questions for solution or discussion.

Send in solutions of questions asked.

Send examination papers in the sciences.

Proposed by E. E. Burns, Medill High School, Chicago, Ill.

A steel spring is wound up. It is then dissolved in acid. What becomes of the energy which the spring is supposed to possess on account of its tension?

Proposed by Charles H. Karns, Bradford, Pa.

A man weighs 150 pounds on a spring at the equator. What would he weigh at the north pole? On the moon? On the sun? What would he weigh at each of these places on a platform balance?

An advertising curiosity. E. H. Sothern's "Lord Dundreary" nature fake riddle. (1,000 answers were received on the first day of its insertion in the New York Sun.)

If 14 dogs with 3 legs each can catch 48 rabbits with 76 legs in 25 minutes, how many legs must 24 rabbits have to get away from 3,000 dogs with no legs at all?

Wanted.

Twenty good questions for examination papers in both physics and chemistry. Pick out your best, not necessarily your hardest question, and send it in.

In the April number of School Science and Mathematics the following problem was proposed:

There is a train of flat cars one mile long traveling at a rate of one mile a minute. A man stands on the front end and also one on the rear end who has a rifle that will shoot a ball at a rate of one mile a minute. When he shoots at the man on the forward end will the bullet reach him?

Answer by W. T. Brewer, Quincy, Ill.

Yes. The rifle is traveling with the train at the rate of one mile a minute, and a ball fired from it at a speed of one mile a minute travels one mile a minute faster than the train; consequently the ball will reach the man in one minute.

Should the man on the front end shoot at the man on the rear end, the ball would hit him—or, rather, he would hit the ball—in one minute; for the ball would not move with reference to the earth, and so in one minute he would run up against the ball.

Please send copies of examination papers in the sciences to the editor of the department.

NORTHERN OHIO GEOGRAPHY AT THE N. E. A.

By W. M. Gregory,

Central High School, Cleveland, Ohio.

The meeting of the National Educational Association at Cleveland, Ohio, June 29-July 3, will bring together many teachers, among whom there will be a large number interested in the geography and the industries of the Forest City. There will be afforded ample opportunity, by means of various excusions, to see some of the typical industries and to visit places of general geographic interest. Arrangements are being made with many of the great shops, mills, and manufactories to open their doors to the members of the National Education Association wearing membership badges. As these establishments are many of them the largest of their kind and represent a great variety of manufacturing methods, much may be learned on these visits which will be of special value to the great number of teachers who are concerned with the industrial and vocational training of the children of the public schools.

In Northern Ohio there is a network of steam and electric roads on which the service is cheap and convenient for rapid travel, while the boat lines offer many trips along the shore and to the various islands of Lake Erie. A great variety of enjoyable trips may be taken by the five finely equipped interurban lines out of Cleveland. Amusement parks, lake shore beaches, pretty little villages, college towns, river glens, beautiful lakes, the garden and fruit lands and vineyards of Northern Ohio, all form numberless attractive destinations. To the east by the Cleveland, Painesville & Eastern Trolley Line are Willoughby, Mentor, the former home of President Garfield; Painesville, the location of Lake Erie College; and Ashtabula with its great harbor and ore docks. Southeast, by the Eastern Ohio Traction Company, are picturesque Gates Mills and Chagrin Falls, Punderson and Bass Lakes, and Chesterland Caves. By the Northern Ohio Traction Company one may reach Canton, the home of the late President McKinley, where the McKinley Memorial is located; Meyers Lake; Akron, the seat of Buchtel College; Bedford Glens, Boston Ledges, Cuyahoga Falls, Silver Lake, Crystal Lake, Summit Lake. Oberlin, with its famous college, Wooster, with its university, Berea with Baldwin University and German-Wallace college are on the Cleveland, Southeastern & Columbus Trolley Line. The cities of Norwalk and Elyria are on this line, as well as North Amherst, with its famous sandstone quarries, Puritas Springs, and Rocky River. The Lake Shore Electric Railroad runs between Cleveland and Toledo along the lake shore. On this line is Lorain, Sandusky, and Rock River.

The Central Association of Science and Mathematics is arranging a special excursion by boat to Kelley's Island and Put-in-Bay.[1] It is

[1]It is planned to charter a boat and about six hundred persons must be secured. Fare is $1.00. Correspondence should be addressed to Franklin T. Jones, President of the Association, University School, Cleveland, Ohio. The local committee of the N. E. A. Department of Science Instruction is planning on various excursions. For information address any member of the committee, Dayton C. Miller, chairman, Cleveland, Ohio. George Eisenhard, George R. Twiss, Herbert C. Wood and Charles F. Dutton.

planned to spend ample time at Kelley's Island to see the glacial features and Inscription Rocks. There will be an opportunity at Put-in-Bay to visit the famous caves and other points of special interest.

If it is desired to visit several of the various geographic regions about Cleveland, the following suggestions will be of service in directing attention to the important areas, and the brief descriptions will indicate what may be found in the various localities. In attempting field work one must have the accurate contour maps issued by the United States government for the entire southern shore of Lake Erie from Toledo to Buffalo. A postal card sent to the Director of the United States Geological Survey, Washington, D. C., asking for the index map of Ohio, will bring a small map showing all the sections of the state that have been accurately surveyed. These relief maps are printed on sheets 18x13 inches and show a district of about 236 square miles; they cost 5 cents each, or 3 cents each when 100 or more are ordered. On the maps all the highways, railroads, villages, etc., are printed in black, while the lakes, rivers, canals, etc., are in blue, the elevations of various places are printed in brown figures, and by the contour lines the altitude of any point can be determined. The following list of sheets from Ohio is suggested as offering a suitable guide in selecting some material for a few days study in the field:

Sandusky,	Oberlin,	Berea,
Massillon,	Kent,	Chardon,
Put-in-Bay,	Mentor,	Perry,
Akron,	Conneaut,	Cleveland,
Cleveland and vicinity,	Ashtabula,	Garretsville.

If the maps are cut in small squares and mounted with paste on good muslin, they are easily folded and carried in the pocket. In starting on a trip, it is well to plan carefully all the details and select the roads from the maps. If there are several members of the party, a collection bag for rocks, a case for plants, and several good cameras should be a part of the outfit. The camera is indispensable on a vacation trip, and many of the views will later furnish excellent lantern slides for presenting regional geography to the student. The suggestions which are outlined below embrace only the more striking features and in the limited space are necessarily very brief.

The Sandusky region west of Cleveland is a splendid type of an embayed plain with drowned river channels and great stretches of encroaching marshes. Several days could be spent in this vicinity, using the large hotel at Cedar Point as headquarters. It is nearly seven miles from the end of Cedar Point along the shore to the land, and there are a great variety of beach and shore features, including wave cutting, formation of sand ridges, bars, spits, and dunes. While the land has been sinking, Cedar Point has increased in length and has been built over and buried some of the former river channels which are easy to trace.[2]

[2]The Formation of Sandusky Bay and Cedar Point, by Prof. E. L. Moseley, Vol. 4, part 5; Proceedings of the Ohio Academy of Science.

The islands northwest of Cedar Point afford a chance to see some of the erosive effects of the great ice sheet upon the bedrock. At Kelley's Island, easily reached by boat from Sandusky, the Corniferous limestone has been deeply grooved; some of these grooves are five feet in depth and ten feet wide and have been preserved by the Western Reserve Historical Society of Cleveland. Someone has suggsted that the tortous grooves have been caused by a sub-glacial stream carving channels which were occupied later by the ice which smoothed and polished them. The straight single grooves have their origin in the cutting of the limestone by very hard rock in the lower part of the ice, some of these are very broad and are fluted and compounded in various ways. Kelley's Island has been for years the mecca for students of glacial geology and in the famous Inscription Rock which rests on the south shore the archæologist finds a romantic story of the Indian tribes which formerly held this ground. Inscription Rock lies on the south side of this island about 80 rods east of the steamboat landing. The Rock is 32 feet greatest length and 21 greatest breadth, 11 feet high above the water in which it rests. It is part of the same formation as the near-by bed rock of the island, from which it has been "plucked" by glacial action. The tops presents a smooth and polished glaciated surface, and upon this the inscription is deeply cut. Schoolcraft's Indian Antiquities says: "It is by far the most extensive and well sculptured and best preserved inscription of the antiquarian period ever found in America."

The Put-in-Bay group consisting of North, Middle, and South Bass, Rattlesnake, Green and Sulphur Islands, have much of interest in caves, deposits of cals spar, native sulphur, celestite and numerous sink holes. The bed-rock is the Waterlime containing fossils of many of the lower reptiles. On South Bass is Put-in-Bay, the famous summer resort, and the island has many caverns dissolved out of the rather porous limestone. "Perry's Cave" is the largest one on the island and was once an underground channel which even now leads to the lake. The water of this cave rises and falls with the fluctuations in level of Lake Erie. The walls have stalactites, and in parts of the cave they are under the water, showing the gradual sinking of the land. "Crystal" cave on the same island is completely lined with large crystals of celestite. This mineral is rather rare and the islands of this group enjoy the distinction of having the largest deposits in the world. One of the group contains so much of the mineral that it is frequently called Strontian Island.

The Oberlin and Berea contour maps, when placed together show the ridges or beaches of the former glacial lakes which existed at a higher level than that of Lake Erie. The old beaches are 10 to 15 feet in height and roughly parallel with the present lake shore. The track of the Cleveland, Elyria and Western Electric road is on the crest of the Middle Ridge, just east of Elyria, while five miles to the east the road changes to another beach called the Butternut Ridge. In the vicinity of Elyria the beaches of Lake Warren, Whittlesley and Maumee are near together and convenient for field study. The North Ridge, about 4 miles north of Elyria, is the well developed beach of Lake

Warren which can be easily traced across Ohio, passing through Elyria is the Belmore beach of Lake Whittlesley and four miles south is the double crested beach of Lake Maumee. The industries of this particular section might prove of interest to some students of geography. At Lorain are very active shipyards, steel and iron mills and the largest steel tube mill in the world. At North Amherst the stone quarries are worked on a very extensive scale and have supplied for many years a gray sandstone which is famous for its quality and the quantity seems to be inexhaustible. The quarries at Berea supply an excellent quality of grit stone which is manufactured into whetstones and various kinds of grindstones. The small falls at Elyria and Olmstead are good illustrations of the manner in which almost all the streams of the northeastern part of Ohio have cut back their bed since the glacial period. A little exploration west of the mouth of the Rocky river along the shore of Lake Erie will reveal the buried preglacial mouth of the river. The preglacial channel which is filled with a hundred feet of glacial drift, has been traced from Lake Erie southward, passing east of Berea. The present course of Rocky river crosses this buried channel west of Kamms and near Binola. This river has several interesting illustrations of "cut off" spurs, the best of which are the two "islands" standing on the flood plain near Olmstead.

The Kent, Akron and Cleveland map sheets have areas equally as interesting as the various places above noted. The Cuyahoga river, called "cuyahaga" or crooked river by the Indians, is a source of much material for the study of the history and the geography of the Western Reserve. The river has the shape of a great "U" with its source, 30 miles east of the mouth, in Geauga county in the bed rock of the Carboniferous conglomerate and the great bend of the river is a short distance north of Akron. The conglomerate consists of masses of snow white pebbles of quartz firmly cemented together. It is a rather porous rock but does not weather rapidly and to-day it forms many of the hill tops in Northern Ohio. The resistant character of the conglomerate causes it to form high bluffs and ledges. The Thompson, Nelson and Boston ledges are of this formation and range from 40 to 80 feet in height. This rock is also well exposed near the source of the Grand river at Parkman, which is west of the Cuyahoga's headwaters and to reach Lake Erie, the Grand flows almost around the source of the former river.

The Cuyahoga valley in the upper part of the river at Burton is marshy and shallow, its features are so entirely different from what would be expected from the conditions in its lower and middle course, that it is difficult to recognize it as part of this stream. The upper course of the Cuyahoga has been determined by glacial deposits, which caused the stream to flow south, and near Akron it was forced west into a deep preglacial valley. In getting into this old valley, the river descends about 200 feet in three miles and has cut a narrow deep gorge of over three miles in length at Cuyahoga Falls. At some places in this gorge the walls are quite near together, while the softer rock beneath the top ledges has been worn away. In early pioneer days, if we can believe the story concerning Brady's Leap, the ledges on the opposite

sides of the gorge were about 22 feet apart but at the present time its narrowest place is over forty feet. The water at the Falls is checked by a series of dams for water power, which is used in a limited way and the early prophecy that this was to be in the future the Lowell of the west has not been fulfilled. It is now a place easily reached by electric cars from Cleveland and much visited for its beauty in the series of small falls, the high ledges and the picturesque arrangement of the small mills along the stream.

It is between the Falls and Akron that the river makes the great bend and turns north. The preglacial valley in which it flows to the north is rather narrow and deep. This valley to-day is partly filled with silt and glacial gravels, so the present river is not cutting on the old stream bed but is removing the material which covers it. The extent and the depth of this old valley have been determined by the many wells that have been drilled for gas, water and oil. At Akron glacial material fills the bottom of this valley to the depth of over 300 feet and it was partly this deposit that diverted the river to the north. In various places between the Falls and Cleveland the sides of the preglacial valley come quite near together and often form rapids or falls. At Boston the valley is not more than half a mile wide and its sides are 100 to 150 feet above the river which is cutting at the deposits of gravels and silt which are 200 to 300 feet deep. The small branches of the river are short and swift, cutting narrow and deep ravines in the soft sandstones and shales of the valley sides. In many of these it is possible to find a complete rock section. In the Brandywine, the lower gray rock is the Erie shale, which forms the extensive outcrops on the shore of Lake Erie, above it is a small layer of the black bituminous Cleveland shale, and still higher is the red Bedford shale. On top of the shales and forming the projecting ledges, is the hard Berea sandstone where the Brandywine creek causes a small but splendid fall 40 to 50 feet in height and supplies power for a small mill. Splendid views of the river to the south may be obtained from the high lands north of Chaffee, here the valley is less than half a mile wide and the lines of railroad, highways and canal are forced very near the water's edge.

The Grand river, partially shown on the Ashtabula, Chardon and Mentor maps, flows for more than 30 miles parallel to Lake Erie. Its northerly course is through the old Monongahela drainage system and on the retreat of the ice, a slight moraine blocked its return to Lake Erie and diverted it westward where it reaches the lake near Painesville. The preglacial channel of this stream is near Geneva. South of the village of Madison, the Grand has eroded a narrow gorge, some two hundred feet deep and in places less than a tenth of a mile in width. The early pioneers called this part of the stream the "Grand Canyon." At Fairport the river formerly flowed through the great Mentor swamp into Lake Erie, but the retreat of the lake shore under the attack of the waves combined with the lateral cutting of the river, has formed an open channel to the lake at Fairport Harbor, and about 4 miles of the river has been cut off. Little Mountain, a flat knob of conglomerate and one of the highest places in northern Ohio, is easily reached by wheeling from Willoughby.

THE NEW MOVEMENT AMONG PHYSICS TEACHERS.—CIRCULAR VI.

More than a year has now passed since the issuance of Circular V in this series. This was done because the answers to the last circular showed that the topics proposed for discussion were new to many to whom it was sent, so that discussion at that time did not seem profitable. In all eighty-one answers were received. The summary of the suggestions sent in will be given at a later date, when the topics which they treat again come up for discussion.

In the meantime, the Commission has not been idle. A long list of topics was submitted to its members last June, and each was requested to cross off those topics to which he had any objections. In this way a short list was obtained to which no objection was offered. This list was presented to the commission and discussed by it at a meeting held last January 1 in Chicago. At this meeting it was unanimously voted to print the list without recommendations, and to distribute it. The list is printed below.

At the meeting of the Commission in Chicago, at which twelve members were present, it was voted to organize a symposium on the topic: What should be the purpose of the instruction in physics in the secondary schools? In order to have the expression of opinion very representative, it was agreed that the commission should nominate and elect by correspondence those whom we should invite to take part. Seventeen members sent in nominations, and forty sent in votes on these nominations. The chairman neither nominated nor voted. The twenty men selected by the commission, to whom invitations are now being sent to participate in the symposium, are the following:

Group I. Psychologists and Educators. Presidents N. M. Butler and G. Stanley Hall; Professors John Dewey, William James, and J. Mark Baldwin.

Group II. College Physicists. Professors Henry Crew, A. A. Michelson, R. A. Millikan, J. S. Ames, and E. L. Nichols.

Group III. Normal and Secondary School Men. Messrs H. N. Chute, G. R. Twiss, L. B. McMullen, J. F. Woodhull, W. E. Tower, E. R. Von Nardroff, L. B. Avery, J. C. Packard, E. A. Strong, and H. L. Terry.

It is hoped that the symposium will be ready for publication in the early fall. It will be printed in SCHOOL SCIENCE AND MATHEMATICS, and possibly elsewhere.

The committee of the North Central Association of Colleges and Secondary Schools voted to recommend to that association the adoption of the definition of the unit in physics as drawn up by the Commission; and also the adoption of the list of topics mentioned above, as the minimum list of required topics to go with the definition. This recommendation of the committee was approved by that association at its meeting in Chicago on March 27. This definition will now be used by the association as its standard by which the physics work in the schools accredited by the association is judged. It has already been adopted by the authorities of Cleveland, Ohio, as defining the work in physics in the high schools of that city. The definition and the list of topics as adopted by the North Central Association is as follows:

The Definition of the Unit in Physics.

1. The unit in phyics consists of at least one hundred and eighty periods of forty-five minutes each (equal to 135 hours) of assigned work. Two periods of laboratory work count as one of assigned work.

2. The work consists of three closely related parts; namely, class work, lecture-demonstration work, and laboratory work. At least one-fourth of the time shall be devoted to laboratory work.

3. It is very essential that double periods be arranged for the laboratory work.

4. The class work includes the study of at least one standard text.

5. In the laboratory, each student shall perform at least thirty individual experiments, and keep a careful note-book record of them. Twenty of these experiments must be quantitative; each of these must illustrate an important physical principle which is one of the starred topics in the syllabus of required topics, and no two must illustrate the same principle.

6. In the class work the student must be drilled to an understanding of the use of the general principles which make up the required syllabus. He must be able to apply these principles intelligently to the solution of simple, practical, concrete problems.

7. Examinations will be framed to test the student's understanding of and ability to use the general principles in the required syllabus, as indicated in 6.

8. The teacher is not expected to follow the order of topics in the syllabus unless he wishes to do so.

Syllabus of Required Topics.

This list of required topics is not intended to include all the material for the year's work. It is purposely made short, in order that each teacher may be free to supplement it in a way that fits his individual environment. It does include those topics which all agree are essential to a first course in physics, and which are capable of comprehension, at least to the extent specified in number 6 of the definition of the unit, by boys and girls of high school age.

*1. Weight, center of gravity.
*2. Density.
*3. Parallelogram of forces.
4. Atmospheric pressure; barometer.
*5. Boyle's law.
6. Pressure due to gravity in liquids with a free surface; varying depth, density, and shape of vessel.
*7. Buoyancy; Archimedes' principle.
*8. Pascal's law; hydraulic press.
9. Work as force times distance, and its measurement in foot-pounds and gram-centimeters.
10. Energy measured by work.
*11. Law of machines: work obtained not greater than work put in; Efficiency.

*12. Inclined plane.
*13. Pulleys, wheel and axle.
*14. Measurement of moments by the product of force times arm; Levers.
15. Thermometers: Fahrenheit and Centigrade scales.
16. Heat quantity and its measurement in gram calories.
*17. Specific heat.
*18. Evaporation; heat of vaporization of water.
*19. Dew point; clouds and rain.
*20. Fusion and solidification; heat of fusion.
21. Heat transference by conduction and convection.
22. Heat transference by radiation.
23. Qualitative description of the transfer of energy by waves.
24. Wave length and period of waves.
25. Sound originates at a vibrating body and is transmitted by waves in air.
*26. Pitch and period of sound.
*27. Relation between the wave length of a tone and the length of a string or organ pipe.
*28. Resonance.
29. Beats.
30. Rectilinear propagation of light: pin-hole camera.
*31. Reflection and its laws; image in a plane mirror.
*32. Refraction, and its use in lenses; the eye, the camera.
*33. Prisms and dispersion.
34. Velocity of light.
35. Magnetic attractions and repulsions.
*36. Field of force about a magnet.
37. The Earth a magnet; compass.
38. Electricity by friction.
39. Conductors and insulators.
*40. Simple galvanic cell.
*41. Electrolysis; definition of the Ampere.
*42. Heating effects; resistance; definition of the Ohm.
*43. Ohm's law; a definition of the volt.
*44. Magnetic field about a current; electromagnets.
*45. Electromagnetic induction.
*46. Simple alternating current dynamo of one loop.
*47. Electromagnetic induction by breaking a circuit: primary and secondary.
48. Conservation of energy.

At the regular meeting of the Physics Club of New York held March 7th, the following resolution, indorsing the principles of the North Central Association's Definition of the physics unit, was passed:

Resolved, That a uniform course in physics for all schools is both undesirable and unattainable. We therefore recommend:

1. That syllabuses should deal with the barest outline of general principles, leaving each teacher free to fill up the course according to his best judgment.

2. That examinations for College Entrance should be confined to the general principles specified in the syllabus, and that a teacher's certificate should be accepted for other material—this might well take the form of a rather full statement of the work done.

This same resolution was passed by the Physical Science Section of the High School Teachers Association of New York City, at its meeting on March 14; by the Eastern Association of Physics Teachers, at a meeting held March 28; and by the Council of the New York State Science Teachers Association, by written ballot.

At its meeting on April 3, the Physics Conference of the Michigan Schoolmasters' Club approved everything in the definition of the unit of the North Central Assocation excepting that part relating to the syllabus. In regard to this, the conference was unanimously of the opinion that a syllabus is not desirable.

The College Entrance Board appointed a committee to frame a new definition of the physics unit for their use. Five members were appointed by the Board itself, and two by each of the four associations of colleges and preparatory schools in the country. This committee is expected to make its report next fall.

Now that this administrative part of the work of the Commission is practically done for the present, its attention will be turned toward the educational phase of its work. The symposium described above is the first step in this direction.

This circular is being distributed widely, in order to call the attention of those interested in the physics situation to the action of the North Central Association of Colleges and Secondary Schools. This action has a very important bearing on the work in physics in the middle west at least. Further documents issued by the Commission cannot be so widely distributed unless some method of meeting the expense is found. The expenses up to date have been partly met by contributions from the North Central Association of Colleges and Secondary Schools, the Central Association of Science and Mathematics Teachers, the New York State Science Teachers Association, and the Physics Club of New York. Reprints of the promised symposium will be sent to those who send requests for it to the chairman of the Commission, C. R. Mann, the University of Chicago.

ARTICLES IN CURRENT MAGAZINES.

Forestry and Irrigation for April: "Arbor Day—The American Spring Festival," Wm. C. Lee, illustrated; "Shall Uncle Sam Drain the Swamps?" illustrated; "Tree Planting in School Yards," Louise Klein Miller, illustrated; "California Irrigation Needs Forests," Lewis E. Aubury, illustrated; "Protection for American Industry," Hon. A. F. Lever.

Journal of the American Chemical Society for March: "Interrelations of the Elements," Herbert N. McCoy.

Nature-Study Review for March: "Elementary Agriculture in High Schools," A. B. Graham; "Agricultural Education at Washington Meeting of N. E. A.," D. J. Crosby; "School-Garden Helps," C. M. Weed; "A Rural School-Garden," Ruth B. Fisher; "School-Gardens of Cleveland," Louise K. Miller; "Our Experience with a School-Garden," M. A. Bigelow; "Nature-Study Lessons Observed," M. A. Bigelow.

Nature-Study Review for May: "Organization of Nature-Study in Primary Grades," B. M. Davis; "Some Fundamental Needs in Nature-Study," M. F. Guyer; "Causes of Defective Methods in Teaching Nature-Study," F. M. Perkins; "Nature-Study at Ohio State University," H. Osborn; "Organizing a Field Trip," H. M. Benedict; "Nature-Study and Preservation of American Game Birds," C. F. Hodge.

Physical Review for April: "Some Studies on the Change of Electrical Resistance of Selenium Cells," F. C. Brown and Joel Stebbins; "Pendulum Coincidences Determined by Shadow Reënforcements, Shadow Micrometry, etc.," C. Barus; "A Satisfactory Form of High Resistance," G. W. Stewart; "On Physical Lines of Force in Electrical Theory," Fernando Sanford; "Studies in Thermo-Luminescence—Variations in the Decay of Phosphorescence in Sidot Blende Produced by Heating," C. A. Pierce.

Physical Review for May: "Experiments on the Induction of Currents in Cylindrical Cores," Roy T. Wells; "Induction Coils," Benj. F. Bailey; "A Differential Volumenometer," Albert P. Carman; "The Variation of Apparent Capacity of a Condenser with the Time of Discharge and the Variation of Capacity with Frequency in Alternating Current Measurements," B. V. Hill.

Popular Science Monthly for May: "Some New View Points in Nutrition," Professor Russell H. Chittenden; "The Utilization of Auxiliary Entomophagous Insects in the Struggle against Insects Injurious to Agriculture," Professor Paul Marchal; "Of the Soil of the Earth," Spencer Trotter; "The Conservation of the Great Marine Vertebrates—Imminent Destruction of the Wealth of the Seas," Dr. G. R. Wieland; "The Whiter Pittsburgh," John F. Cargill; "The Education of the Colored Race is the Duty of the Nation," Professor Harris Hancock; "Should Psychology Supervise Testimony?" Fabian Franklin.

Review of Reviews for April: "To Farm America's Swamps," by G. E. Mitchell; "National Forests in the Appalachians," by T. E. Will; "The Greatest Naval Cruise of Modern Times," W. L. Marvin; "The Nation's Anti-Drink Crusade," by F. C. Iglehart.

School World for April: "The Inherited Habits of Domestic Animals," E. Stenhouse; "Map Drawing as a Part of School Work," E. F. Elton, illustrated; "Manual Instruction in Wood—A Course for Secondary Schools," J. W. Riley, illustrated; "Methods of Approach in Geographical Instruction," George G. Chisholm.

Scientific American for April 11: "The Henry Hudson Memorial Bridge"; "The Recent Work of Luther Burbank," Riley M. F. Berry; "Trachodont, the Duck-Billed Dinosaur—Skeletons of Prehistoric Reptiles More than Three Million Years Old," Barnum Brown.

Scientific American Supplement for April 11: "Electrical Machinery in Steel Making," W. T. Dean, illustrated; "The Basis for a New Ecology—IV," H. W. Pearson. For April 18: "The Marseilles Concrete Dam," J. H. Goodell, illustrated; "Fixation of Atmospheric Nitrogen," Prof. Th. Schloesing; "Some Snakes and other Reptiles," Raymond L. Ditman, illustrated. For April 25: "The Quebec Bridge Disaster," Report of the Commission; "The Photography of Color—I," Chapman Jones; "Farming the Kangaroo," Harold J. Shepstone; "The Ether of Space," Sir Oliver Lodge; "The Origin of Continents and Oceans," Prof. A. E. H. Love. For May 2: "Elements of Electrical Engineering—Alternating Currents, Part II," A. E. Wilson; "The Photography of Color—II," Chapman Jones; "The First Weather Plant Observatory," Harold J. Shepstone; "The Latest Work on the Solar Parallax," Abbé Moreaux.

Technical World for April: "Shooting to Hit with Big Guns," Livingston Wright; "What of the New Cactus?" E. S. Merriam; "The Magic of the Magnet," George Frederic Stratton; "Wild Beasts that Hunt to Order," Capt. Francis Thatcher; "First Train Goes Out to Sea," M. B. Claussen; "New Destroyers of Bacteria," P. J. Preston; "How Artificial Diamonds are Made," Frederic Lees; "The Making of Meerschaums," Fritz Morris.

DO SCIENCE TEACHERS APPRECIATE THEIR OPPORTUNITY?

OTIS W. CALDWELL.

In a most stimulating book entitled "The Kingdom of Man," by E. Ray Lankester, there is presented the idea that science men fail to see the bearing of science upon the educational possibilities of the present time. Science knowledge has rapidly come to reorganize the world's ways of doing things and ways of thinking, but in formal education science is not nearly so fully recognized as in practical life and thought. It is much more easy for us to readjust our practical life and thought than our formal education, which is supposed to be a preparation for a wider practical life and thought. The following quotation from Professor Lankester offers material for extended consideration:

"THE REGNUM HOMINIS.

"As a matter of fact the new knowledge of Nature—the newly ascertained capacity of man for a control of Nature—so thorough as to be almost unlimited—has not as yet had an opportunity for showing what it can do. A lull after victory, a lethargic contentment, has to some extent followed on the crowning triumphs of the great Nature-searchers whose days were numbered with the closing years of that nineteenth century which through them marks an epoch. No power has called on man to arise and enter upon the possession of his kingdom—the 'Regnum Hominis' foreseen by Francis Bacon and pictured by him to an admiring but incredulous age with all the fervor and picturesque detail of which he was capable. And yet at this moment the mechanical difficulties, the want of assurance and exact knowledge, which necessarily prevented Bacon's schemes from taking practical shape, have been removed. The will to possess and administer this vast territory alone is wanting."

A new process, originated in France, for the manufacture of precious stones has lately attracted considerable attention on the part of leading European scientists. Forty of these artificial gems were submitted to the Museum of Natural History at Berlin, and the appointed committee of experts reported as follows: "Of the variety of stones we examined we were favorably impressed only by the artificial rubies. Among these were some of great beauty and worthy of consideration. The white sapphires were of no account at all; they appeared dull and washed out. Well imitated were the yellow precious stones; they really resembled the topaz very closely; but this invention carries with it only very little value, since the real topaz is found in such large quantities that they sell at from 2 to 3 marks (47.6 cts. to 71.4 cts.) a gram. Therefore, it would seem of little importance to imitate such common stones. Of all the stones we examined, we can only call the artificial rubies a direct success; but the imitation of this latter species of precious stones is no new invention. We therefore declare that there is nothing new or sensational in the claimed invention."

NORTHERN CALIFORNIA MATHEAMTICS TEACHERS.

An association of the mathematics teachers of Southern California was formed in December, 1906.

Meetings have been held every two months for the purpose of improving the teaching of mathematics. Realizing the need for more concrete teaching of geometry, the association has resolved itself into committees, whose purpose is to examine and classify the simpler applications of geometry, with a view to forming a handbook for class-room use.

The executive committee consists of Mr. F. Brackett, Pomona College, Chairman; Miss T. Brookman, Redlands High School, Secretary; Mr. John B. Cleveland, Los Angeles Normal School.

UTAH ACADEMY OF SCIENCE.

At a meeting held at Salt Lake City in the Packard Library Auditorium, Friday evening, April 3, 1908, the Utah Academy of Science was organized by the adoption of a constitution and the election of the following officers:

President, Dr. Ira D. Cardiff, Univ. of Utah; First Vice-president, Dr. John A. Widtsoe, Utah Agr. College; Second Vice-president, Dr. S H. Goodwin, Procter Academy; Secretary, A. O. Garrett, Salt Lake High School; Treasurer, E. M. Hall, L. D. S. Univ.; Councilors, Dr. John Sundwall, U. of U.; Dr. E. D. Ball, Agr. Coll.; Dr. W. C. Ebaugh, U. of U.

Three sessions were held, during which the following program was given:

"The Primordial Element: A Recurring Hypothesis," Dr. W. C. Ebaugh; "Origin and Distribution of the Flora of the Great Plateau," Prof. Marcus E. Jones; "Results of Some Investigations of Parasitic Insects," Prof. E. G. Titus; "Notes on the Nesting Habits of the Genera Bombus and Osmia," Dr. Philena Fletcher Homer (In the absence of the author this paper was read by Mr. Geo. W. Bailey.); "The Origin of the Homopterous Fauna of the Desert," Dr. E. D. Ball; "Rusts and Smuts of Salt Lake and Adjacent Counties," A. O. Garrett; "Concerning the Radiation from the Nernst Lamp," Dr. L. W. Hartman; "Refractory Clay, and the Effects of Ingredients upon the Melting Point," A. F. Greaves-Walker; "Recent Researches Bearing upon the Physical Basis of Heredity," Dr. Ira D. Cardiff; "Researches on Gland Cells," Dr. John Sundwall.

A motion carried empowering the Council to make arrangements for a July excursion to some of the neighboring points of interest.

A. O. GARRETT, Secretary.

IOWA ASSOCIATION OF SCIENCE TEACHERS.

This organization was formed at the meeting of the State Teachers' Association held at Des Moines during the holidays. It was felt that there was need in Iowa for a more formal organization than that of the Round Table of the general association and this association is the result.

A committee of local science teachers had met previous to the meeting at Des Moines and drawn up a constitution which had been mailed to science teachers over the state. This constitution was adopted and the following officers elected: President, Prof. F. F. Almy of Iowa College; vice-president, Miss Stella Tuttle, East Waterloo High School; secretary-treasurer, F. E. Goodell, North High School, Des Moines; leader of biology section, J. R. Locke, Creston High School; physics section, George W. Tidd, Ft. Dodge High School; chemistry section, E. C. Converse, Burlington High School; physiography section, Prof. E. J. Cable, Iowa State Normal.

To provide for carrying on correspondence, issuing reports, etc., members are to pay annual dues of fifty cents. An indicated above the association is divided into four sections each to provide its own meetings together with such general meetings as may be held.

The annual meeting will be held in connection with the general association. It is planned to make the program of this meeting more extensive and helpful. It is the aim of the association to provide sectional meetings in various parts of the state.

Aside from more inspiring meetings it is hoped that the association will be able by means of its dues to place in the hands of its members reports of progress in science and science teaching and other helpful literature. There is no reason why this association if supported by the science teachers of the state should not prove of immense help in unifying and making more efficient the science work in the secondary schools of Iowa.

REPORT OF THE MEETING OF THE ASSOCIATION OF TEACHERS OF MATHEMATICS IN THE MIDDLE STATES AND MARYLAND.

The tenth meeting of the Association of Teachers of Mathematics in the Middle States and Maryland was held at Goucher Hall, the Woman's College of Baltimore, Baltimore, Md., on March 14.

The meeting of the council preceded the regular session, and the council passed a motion affiliating this association with "The American Federation of Teachers of the Mathematical and the Natural Sciences."

The morning session was called to order at eleven o'clock, and as President Goucher was unable to be present, Dr. Maltbie, as his representative, welcomed the members of the Association. The minutes of the meeting of November 30, 1907, were read and approved, and the Secretary reported that the Association had now five sections, Philadelphia, New York, Pittsburg, Rochester, and Syracuse, and that the membership had increased to 530.

The morning program was then taken up, the following papers being read and discussed:

1. "Undergraduate Instruction in Mathematics," L. S. Hulbert, Johns Hopkins University.

2. "Our Duty as Teachers," I. J. Schwatt, University of Pennsylvania.

3. "Notes on the Teaching of Mathematics in English Preparatory Schools and Colleges," William H. Jackson, Haverford College.

At the end of the morning session an invitation from Dr. Goucher was extended to the members of the Association to attend a luncheon which was served in the college lobby. The members of the Association of History Teachers in the Middle States and Maryland, which was in session on the 13th and 14th, were also invited to the luncheon. After an unusually pleasant luncheon, the President of the History Association and Dr. Schwatt of the University of Pennsylvania for the Mathematics Association, expressed the appreciation of the Associations for their entertainment.

The afternoon session was a joint session with the Baltimore Association of Teachers of Mathematics, and their President, Dr. Cohen, was asked to take the chair. The following papers were then read:

1. "A Test of Elementary Text Books in Geometry," Frank Morley, Johns Hopkins University.

2. "The History of Mathematical Symbolism" (illustrated), Albert J. Gminder, Walbrook Schools.

After the reading and discussion of the papers the meeting was adjourned.

A report of this meeting would be incomplete without mention of the excellent address given by Ambassador Bryce on Friday evening. By the courtesy of the History Association, the members of this Association were invited to attend the open meeting on Friday evening, and many availed themselves of the opportunity.

EUGENE R. SMITH, Secretary.

INDIANA ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS.

The Indiana Association of Science and Mathematics Teachers met at the Shortridge High School, Indianapolis, on Saturday, April 25. The general session was held in the morning, and sectional meetings in the afternoon.

In the president's address, Mr. O. W. Douglas of the Anderson High School made a strong plea for the introduction of industrial and practical applications in science teaching. Supt. Fred J. Breeze of Remington spoke of "Physiography in Field and Laboratory," presenting a suggestive outline of a course of experiments and exercises, which in the hands of a good teacher cannot fail to be effective. Prof. Stanley Coulter of Purdue University delivered the principal address on the subject, "What are the Limitations of High School Science?" His ideas were especially helpful to the teachers, from the fact that he is thoroughly acquainted with the work in Secondary Schools.

Prof. Ransom of Purdue University presided at the meeting of the Physics and Chemistry Section, at which the following program was presented:

I. Gems and Precious Stones: Frank B. Wade, Shortridge High School, Indianapolis.

Mr. Wade presented his subject in a very entertaining and instructive manner, illustrating it by means of many beautiful specimens.

II. "Waves versus Rays in Elementary Optics," R. F. Ratliff, Central Normal College, Danville.

The speaker urged the introduction of the conception of the wave theory in the teaching of optics, illustrating its application to the explanation of such phenomena as reflection and refraction. A lively discussion followed in which he was severely criticised, and the method of presentation by means of rays, upheld as simpler and equally satisfactory.

III. The Importance of Teaching the Principles of Wave Motion. Prof. C. M. Smith, Purdue University.

Prof. Smith illustrated his remarks with a number of fine lantern slides, reproducing Prof. Wood's well-known photographs of sound waves in air, and showing clearly the phenomena of reflection, refraction, and interference.

IV. Symposium. "How I Teach Mechanics," B. F. Steele, Marion High School.

Discussion led by Lynn B. McMullen, Shortridge H. S.

A spirited general discussion followed.

Prof. Dennis of Earlham College presided at the meeting of the Biology Section, and the following program was presented:

I. Physiology in the High School. B. W. Kelley, Richmond.

II. The Advisability of a Course in Biology in the High School. Hugh E. Johnson, Greenfield.

Mr. Johnson raised the question of presenting a preliminary course in Biology rather than separate courses in Botany and Zoölogy. The plan was not generally approved.

III. The Proportion Between the Practical and the Purely Scientific in Botany. Miss Etoile Simons, M. T. H. S., Indianapolis.

Miss Simons made a strong plea for the thorough teaching of the principles of Botany, to be followed by practical applications, and objected to the introduction of much of the so-called practical matter, which is often foreign to the work in hand.

IV. The Camera in Science. J. F. Thompson, Richmond.

Mr. Thompson showed in an interesting way how the camera may be used to advantage in the study of plants and animals.

A general discussion of the papers followed.

Walter W. Hart of Shortridge presided at the meeting of the Mathematics Section. The program was as follows:

I. *Symposium.*—The Purpose of Instruction in Mathematics.

1. F. O. Hester, M. T. H. S. Indianapolis.
2. Prof. D. A. Rothrock, Indiana University.
3. H. D. Merrill, Fort Wayne High School.
4. E. R. Ray, Supervising Principal, Indianapolis.
5. Prof. A. M. Kenyon, Purdue University.
6. General Discussion.

INTERMISSION.

II. Some Devices for Making Instruction in Mathematics of Practical Use.

1. A. B. Wright, Anderson High School.
2. J. W. Woodhams, Shortridge H. S., Indianapolis.

At the brief business session the question of joining the American Federation was presented, and the Association referred the matter to a committee composed of the incoming and retiring officers.

The following officers were elected for the ensuing year:

President, George A. Abbott, Manual Training H. S., Indianapolis.

Vice-President, Prof. M. A. Thomas, Wabash College.

Sec.-Treas., H. F. A. Meier, Muncie High School.

Chairman Ex. Com., W. W. Hart, Shortridge H. S., Indianapolis.

G. A. ABBOTT.

PHOTO-ERA MAGAZINE FOR MAY.

The experiences of a practical photographer in Alaska furnish material for the principal feature of *Photo-Era Magazine* for May. The article and beautiful accompanying illustrations are by George R. King, of Boston, an extensive traveler and successful photographer. Graft in the making of graduating-class photographs in the public schools is also a timely and important topic which is discussed at length. Other distinctive articles are "Gum-Bichromate Printing," by Eleanor W. Willard; "Ozobrome Prints from P. O. P. Possible." by William Findlay; "Disadvantages of Working in Miniature," by David J. Cooke; "Home Portraiture Using an Ordinary Window," by Felix Raymer; "Some Notes on Composition in Landscape," by Horace Mummery. The issue contains a wealth of beautiful illustrations, and the usual departments are bright, timely and instructive.

BOOKS RECEIVED.

Elementary Algebra, by J. W. A. Young and L. L. Jackson, 1908. Pages, 438. D. Appleton & Co., New York.

A Laboratory Guide for Students in Physical Science, by H. Schappen Univ. of Ark. 12 mo; v+61 pages. Cloth, $1.00. 1908. John Wiley & Sons, New York.

Spectrum Analysis, by John Landauer, LL.D. Authorized English edition by J. Bishop Tingle, Ph.D. Second edition, rewritten, 800 ix+236 pages, 49 figures. 1908. Cloth, $3.00. John Wiley & Sons, New York.

BOOK REVIEWS.

Adressbuch der Deutschen Präzisionsmechanik und Optik und Verwandter Berufszweige, by F. Harrwitz, editor of "Der Mechaniker." Pp. 376. Paper, 8 mk.; cloth, 10 mk. F. and M. Harrwitz, Berlin. W., Potsdamerstr., 113, Villa V, Germany.

Part I is a list of the manufacturers of instruments and apparatus in Germany, arranged alphabetically according to the names of the firms, with the specialty of each firm. Part II is the same list grouped according to the cities in which they are located; and in Part III the names are grouped according to the specialty. H. E. C.

A Scrap-book of Elementary Mathematics, by William F. White, Ph.D., State Normal School, New Paltz, New York. Pp. 248. $1.00. The Open Court Publishing Company, Chicago. 1908.

This volume is made up of a collection of seventy essays, recreations, and notes upon mathematical themes. It presents some of the most interesting and suggestive phases of the subject in a way to inspire a boy who has seen only the dry and dull side of mathematics. The author says in the preface, "Amusement is one of the fields of applied mathematics," and this field is, no doubt, too much neglected. Moreover, there is more than amusement here. When a boy has learned to prove that $2 = 1$, he has learned also, that the axiom, if equals be divided by equals the quotients are equal, is to be used with some discrimination. A few of the titles will serve to indicate the nature and scope of the book: Multiplication at sight; a new trick with an old principle. A few numerical curiosities. General test of divisibility. Numbers arising from measurement. Present trends in arithmetic. Multiplication and division of decimals. Napier's rods. Do the axioms apply to equations? Algebraic fallacies. The three parallel postulates illustrated. Paradromic rings. The three famous problems of antiquity. Linkages and straight-line motion. The mathematical treatment of statistics. Mathematical symbols. Magic squares. Mathematical games and puzzles. The mathematical recitation as an exercise in public speaking. H. E. C.

Useful Birds and their Protection, E. H. Forbush. Published by the Massachusetts State Board of Agriculture, 1907.

This book of 437 pages, 56 plates and 171 figures is one of the most valuable of its kind that has been published. Some of its chapter headings are: "The Utility of Birds in Nature," "The Value of Birds to Man," "Utility of Birds in Woodlands," "Birds as Destroyers of Hairy Caterpillars and Plant Lice," "Economic Service of Birds in the Orchard," "Utility of Birds in Field and Garden," "Checks upon the Increase of Useful Birds," "Protection of Birds," and numerous chapters upon descriptions of birds. The illustrations are excellent, the text good and highly interesting. Citations to the publications of other authors upon the same or similar topics are helpful though not so abundant as should be.

Darwinism To-Day, by Vernon L. Kellogg, Professor in Leland Stanford Jr., University. xii + 403 pages; published by Henry Holt & Co. New York, 1907.

The educated reader, the teacher, and even the student of science find it difficult to read enough to know just what are the latest and most widely accepted theories of organic evolution. They are often in doubt as to how much of Darwin's hypothesis has stood the test of modern criticism and recent investigation, and how much has been replaced by theories which seem to be more in accord with the phenomena of nature. To meet this difficulty and remove this doubt Professor Kellogg has given us a volume, written in a clear and pleasing style, discussing in scientific but non-technical language the present status of the theories of descent and species forming.

Darwinism is defined as formulated by Darwin himself, and also as interpreted by the various schools of his followers. The writer describes the various attacks which have been made upon the theory and the replies which have come from the followers of Darwin. The various theories which have been proposed to replace Darwinism are given careful statement, their merits being freely admitted and their defects criticised. The opinion is given that the great principle of Darwin's theory has remained unshaken and that natural selection is the final arbiter of descent, although it can not be regarded as an efficient causal explanation of species formation. In the formation of new species the principle factors are segregation and variation, sexual selection being much less important than was formerly supposed, but neither Darwinism nor any of the other theories can give a causal explanation of variation, whether fluctuating or mutational.

The discussion of the various workers in this field of science is characterized by fairness and clearness of statement and is sufficiently extensive to give the reader an excellent idea of all the principal theories of evolution now held by the leading biologists of the world. For the benefit of the special student an appendix follows each chapter of the book giving a bibliography and quotations from orginal papers. While thus of service to the research student in zoölogy or botany, it should be indispensable to the teacher of biology, and valuable and interesting to the general reader. GEO. D. FULLER.

A Manual of Practical Physics for Students of Science and Engineering, by E. S. Ferry and A. T. Jones, both of Purdue University. Vol. I. Fundamental Measurements and Properties of Matter and Heat. 273 pp., 112 cuts. Longmans, Green and Co., New York.

It is refreshing to get hold of such a book as this. The names of the authors is a guarantee that the statements and methods used in the book are right. The style and method of presenting, the manner in which the various experiments are to be carried out is clear and to the point. Any instructor using this manual in his laboratory will save much valuable time generally given to explanations, which in this book are presented in such a way as to cause the student to rely, very largely, upon his own resources, thus developing the spirit of self-reliance for which laboratory work of this character is primarily intended. The book is designed to be used in college and technical schools. A good working knowledge of college algebra and triginometry is required.

The typography of the book is most excellent. The cuts and drawings are all new, many of the cuts being taken from apparatus in actual use.

The book consists of two parts. Part I, containing 151 pages, is devoted to experiments on the mechanics of solids and fluids. Part II, of 97 pages, bears directly on heat. There are 16 pages of matter given to physical constants which are used in the experimental work of the book. C. H. S.

The Elements of Physical Geography, by T. C. Hopkins. Benj. H. Sanborn & Co., Boston, 1908.

The Elements of Physical Geography, by Prof. T. C. Hopkins, com-

prises about 500 pages and 316 well-chosen illustrations. As he fittingly says in his preface, "the book is not an experiment." It is born rather out of ripe scholarship and years of experience in teaching the subject at a time when no single text-book was adequate to the demands of the hour.

The teachers of Physical Geography in New York State have encountered great difficulties in bringing their pupils to the high standard of the Regents' Syllabus, but this new work fully covers that broad field. The laboratory manual designed to accompany this book is freighted with helpful suggestions.

The style of the author is exceptionally clear and lucid and peculiarly his own. The last half of the book is stronger and better written than the first half, yet the entire story is told in such a way that the student reads on to the end with interest from the beginning.

The numerous illustrations are widely selected and everywhere intensify the essentials of the text. The economic features are especially commendable. The references at the end of each chapter will prove full of helpfulness to those who would seek a broader knowledge of the subject.

While the subject matter of the text conveniently divides itself into chapters more or less closely related to each other, it does not necessarily follow that they should be taught in the chronological order enumerated, but rather it affords the opportunity for the introduction of that chapter best suited to the environment of the school. Chapter 1 introduces the astronomical aspect of the subject. The pupil becomes familiar with the relations and functions of the various heavenly bodies, and the prevalent theories as to the genesis of the earth and its satellite.

In the second chapter the reader is introduced to the marvelous circulation of meteoric waters, their power and effect, solution, transportation of sediment, together with an outline of the geographic forms that result through the deposition of their burden. The same interesting story is continued through the origin, disappearance, and function of lakes. These two chapters, presenting physiographic causes and effects so clearly and forcibly, constitute a very valuable field for the introduction of the work in many schools.

The fourth chapter involves a discussion of the causes and movements of glaciers and classifies the morainal material abandoned during their retreat. The fifth and sixth chapters are largely devoted to the circulation of oceanic waters and to the phenomena manifested in shore lines.

In the seventh chapter the discussion turns to the land forms. It introduces the reader to those ores that are of great economical importance in the arts and industries, to the more common rock-forming minerals and to the sedimentary, igneous, and metamorphic rocks. Here the author scrupulously avoids the use of the deeper lithological terms that mar the utility of some texts upon physical geography.

The treatment of chapter VIII upon diastrophic movements, volcanoes, and earthquakes is in the light of the more recent eruptions and

earthquake activities peculiarly interesting. Chapter IX is devoted to the larger physiographic features of the land. The story runs smoothly through the description of plains, plateaus, and mountains, the delineation of their structure, and the enumeration of their economic function. Chapter X affords a detailed description of the principles embodied in meteorology and climatology. While some critics may feel that an undue amount of space has been assigned to this part of the general subject, yet in the light of the work established by the U. S. Weather Bureau throughout the country, it will prove one of the most helpful and welcome chapters of the entire work.

The last two chapters comprise a most valuable outline of the geography of animal and plant life, together with the physiographic regions of the United States. They cannot fail to stimulate a keen interest in the pupils' subsequent work in both Biology and Botany.

The entire work reflects a breadth of scholarship that is rare, the wide reading and the well choosing of the subject matter has left no essential feature unnoticed.

Although it is primarily a secondary school book, yet its scope is sufficiently broad for college credits. With its wealth of material no teacher of physical geography or geology can well afford to be without this most resourceful book. C. H. RICHARDSON.

SCIENCE ASSOCIATIONS EXCURSION.

The N. E. A. meets in Cleveland, June 27 to July 3, 1908. A few hours' ride away by boat is Kelley's Island, and a short distance further is Put-in-Bay. At the former place all the industries associated with a limestone quarry are carried on. The island itself is a solid bed of limestone containing innumerable fossils of considerable variety which are very easily accessible. The chief point of interest on Kelley's is, however, the glacial grooves. These indisputable evidences of glacial action on an immense scale are now preserved on a reservation owned by the State. To a teacher of the Natural Sciences these are of even greater interest than to the sightseer.

On Put-in-Bay Island are the fish-hatchery, various natural caves, and especially Crystal Cave, which contains not only the largest deposit of Celestite in the world but crystals that far surpass in beauty and size any other similar deposits.

A committee of the Central Association of Science and Mathematics Teachers will undertake the conduct of an all day lake excursion to these points of interest if there is sufficient demand to justify plans. About 600 people at about $1.00 each will be necessary to pay expenses. If more can be obtained, more can be done for the comfort and amusement of those who take the trip, as this is not designed to be a money-making affair.

Individuals and associations that are interested in making this a success are requested to notify Franklin T. Jones, University School, Cleveland, O. If a sufficient response is received, preparations will be pushed to carry out the plans outlined above.

On account of unavoidable delays we have decided to postpone the first instalment of the Symposiums until the October issue.